device, said sensor placed in electrical communication with said second RF receiver;

97 Cont

d) demodulating and digitizing the ambient RF signals with the second RF receiver; and

e) suppressing the ambient RF signals correlated between the first RF receiver and the second RF receiver with the adaptive filter.

REMARKS

In paragraph 1, the Examiner has objected to the drawings alleging that means to digitize and demodulate the received signals and the converting signals to a corresponding voltage or current must be shown or the features canceled from the claims. Applicant states that the drawings will be amended to show these functions and no new matter will be entered in doing so. However, the drawings have been delayed due to factors beyond the control of applicant and his attorney so that, as soon as they become available, they will be submitted.

The Examiner has rejected Claims 1-18 and 34-38 under 35 U.S.C.§103(a) as being unpatentable over Clough et al (US 4,672,674). The Examiner has also rejected Claims 1-10, 14, 15, 25-27, 34 and 38 under 35 U.S.C.§103(a) as being unpatentable over Chang (US 4,912,767). The Examiner has further rejected Claims 19-24 and 28-33 under 35 U.S.C. §103(a) as being unpatentable over Chang (US 4,912,767) in view of the instant application's admitted prior art. Applicant has canceled Claims 2 and 6 and has amended Claims 1, 3-5, 7, 9-17, and 25-38. Applicant respectfully traverses these rejections and, in

light of these amendments, requests re-examination.

Each of the cited references, including Zurek et al (US 4,956,867) and Schiff (US 4,636,586), are concerned with acoustic or audio signals. Clough et al cancels audio signals. Chang uses the same cancellation process as Clough et al except that he adds narrow band filters before the cancellation process to make audio voice recognition. Schiff uses the same cancellation process as Clough et al except the application is for canceling audio echoes. And, Zurek uses the same cancellation process as Clough et al except that he adds a threshold function to enable or disable the cancellation process for low signal-to-noise ratios. But note, all of these references deal with audio signals.

Audio signals, (acoustic radiation) travels at the speed of sound, much slower than radio frequency (RF) radiation that travels at the speed of light. Applicant's invention clearly states that it is useful for cancellation of radio frequency (RF) signals. The problems with acoustic radiation and the solutions to these problems are not suggested by references that deal only with acoustics. Audio signals typically are in the range of 20 Hz to 20,000 Hz whereas RF signals typically are in the range of several million Hz to several billion Hz. The reason why the Examiner has not cited any patent prior art about RF in the presence of strong ambient signals is that there is no such prior art. The industry has been stymied in this regard and has been using spectrum analyzers, anechoic chambers, and remote open area test sites with all of their drawbacks and problems, explained in detail in the specification. Applicant's invention is the first, truly virtual RF signal analyzer that is free of these drawbacks and disadvantages and that can be obtained at a reasonable cost.

Applicant's invention describes a similar level of modification in HF such as Chang has done to Clough et al with radio acoustics. Chang has added narrow band filters, whereas Applicant has added a demodulator. The cited patents are for the sole purpose of canceling audio signatures. These signatures are directly digitized with A/D converters. The instant patent application states, on page 8, line 28, the use of time, frequency and phase synchronized receivers BEFORE the A/D process. The four cited patents use synchronized A/D converters but Applicant's invention uses synchronized RF receivers before the A/D converters. No such device as applicant's exists, other than that made according to the instant invention, that has fully synchronized two-channel RF receivers. This is what others in the prior art are missing who have tried to cancel RF ambients. This is noted in the specification at page 9, lines 23-35, page 10, lines 1-6, and page 13, lines 13-17. As is shown in the following documents, submitted herein, the RF measurement community, specifically the electromagnetic interference (EMI) community, has been trying to cancel ambient RF signals for more than 10 years. For instance, a competitor, Hewlett-Packard, conducted three (3) years of research in order to accomplish this but failed to develop such a system and abandoned the project. Accordingly, the teachings of Clough et al, Chang, Zurek et al and Schiff have not provided any direction to the industry to cancel RF signatures.

The claims have been greatly amended to show that the invention is limited to RF energy matters, not audio or acoustic signals. In addition, a limitation has been added that the second sensor is placed at a distance from the first sensor of at least ten times the distance

between the first sensor and the device under test. Neither of these limitations appear in or are suggested by the four cited references.

The Examiner is charged with the duty to cite references that teach Applicants' invention, *In re Wood*, 599 F.2d 1032, 202 USPQ 171,174 (CCPA 1979): (...we look to see whether *teachings* render the claimed subject matter obvious") [emphasis the court's]. Here, neither Clough et al, Chang, Zurek et al or Schiff teach, suggest or hint Applicants' claimed invention of measuring radio frequency emissions.

Applicants now present evidence of secondary considerations that are important to his argument that the claimed invention is not obvious within the meaning of 35 U.S.C.§103(a). This evidence may be quite relevant to the issue of unobviousness, *Stratoflex, Inc. v. Aeroquip Corporation*, 713, F.2d 1530, 1538-40, 218 USPQ 871, 879 (Fed. Cir. 1983) "...evidence of secondary considerations may often be the most probative and cogent evidence in the record. It may often establish that an invention appearing to be obvious in light of prior art was not."

The first document, Exhibit A, is a product brochure of the instant invention describing its functions and benefits. The second document, Exhibit B, is a "Readers' Choice" award and "Product of the Week" award, issue by "Evaluation Engineering" magazine describing the instant invention and its benefits. The third document, Exhibit C, is another "Readers' Choice" award from Evaluation Engineering magazine, showing, on page 2 under the heading "EMC", the instant invention as being chosen as one of the best EMC products of 1999. The fourth document, Exhibit D, is an article by the inventor of the

instant invention and others concerning the invention that was printed in the August 2000 issue of Conformity magazine. The fifth document, Exhibit E, is another "Product of the Week" award issued for the instant invention for ChipCenter the Internet's definitive resource. The sixth document, Exhibit F, is a reprint of an article about the instant invention appearing in a recent issue of Compliance Engineering, Evaluation Engineering, Test & Measurement World magazine. The seventh document, Exhibit G, is a reprint of an article about the instant invention for the U.S. Air Force.

Please note that the undersigned was not the counsel of record in this patent application when the Examiner issued his Office Action. However, the assignee of the Patent Applicant, CASSPER Instrumentation Systems, Inc. has recently revoked the Power of Attorney issued to the original patent attorney and has executed a new Power of Attorney in favor of the undersigned. Enclosed as Exhibit H is a copy of this new Power of Attorney. The original Power of Attorney is on its way to the undersigned's office by mail and, as soon as it is received, will be forwarded to the Examiner.

In addition, the undersigned submits his own declaration, as foundation for the claim by Applicant of the commercial success of the invention. That declaration, Exhibit I, indicates that Applicant's assignee has manufactured and sold 47 such units to such well recognized companies as AT&T, General Motors, OTIS elevator, Lucent, and the United States Air Force. Commercial success is a hallmark of nonobviousness.

Applicant's new counsel has amended the claims to clearly indicate that the invention is limited to RF energy. Based upon these amendments, the arguments set forth above, and

the evidence submitted herein, Applicant requests the Examiner to re-examine the claims and withdraw his rejection based upon 35 U.S.C.§103(a).

Applicants' counsel has addressed all issues raised by the Examiner in this first Office Action. If any issues have not been adequately addressed it was purely unintentional and the Examiner is invited to telephone counsel. The application now appears to be in condition for passage to allowance and such action is earnestly solicited.

Respectfully submitted,

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Attorney for Applicant
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e-mail: Jmurphey@mmiplaw.com
Dated: December 5, 2000

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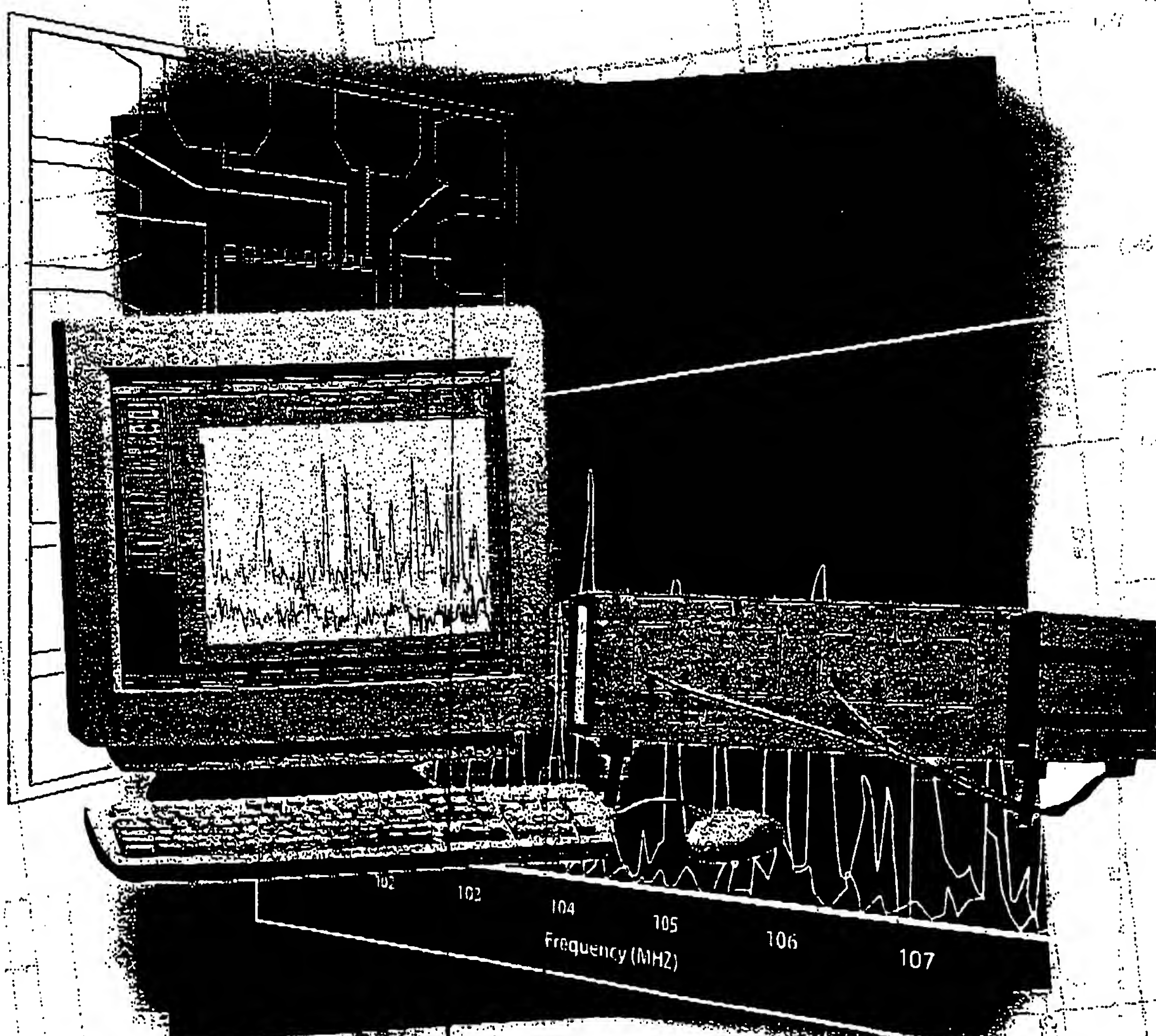
1

Ambient Cancellation/Source Localization

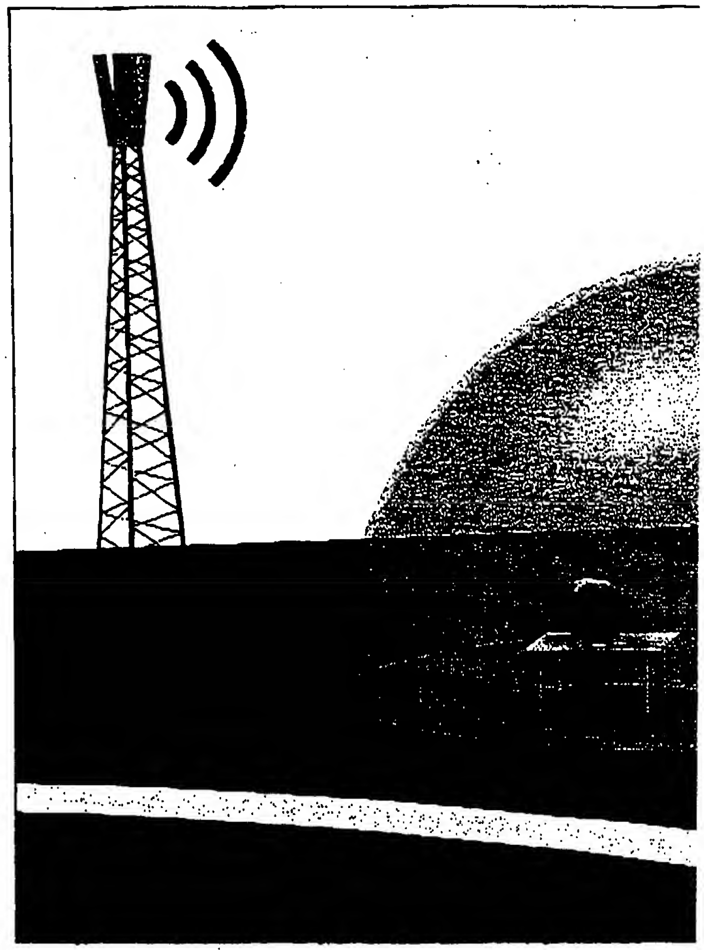
CASSPER®



ETS™

EMC TEST SYSTEMS, L.P. – An ESCO Company

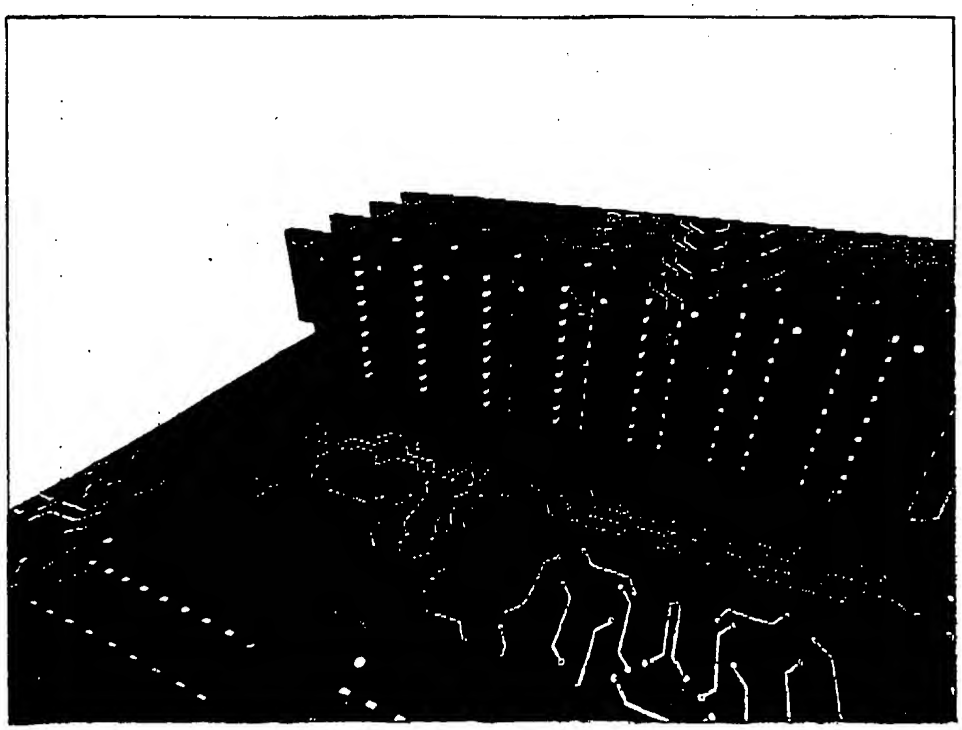
Cancel RF Ambient Noise, Locate EMI Em



The Challenge

In today's crowded RF ambient, higher noise levels often interfere with EMC compliance measurements. Filtering out the ambient and identifying only EUT related emissions requires a lot of time and educated guessing. That's because test instruments like spectrum analyzers identify signal frequency and power level, but not the signal source. It's easy to see how EUT emissions can be overlooked, hidden underneath ambient signals with the same center frequency.

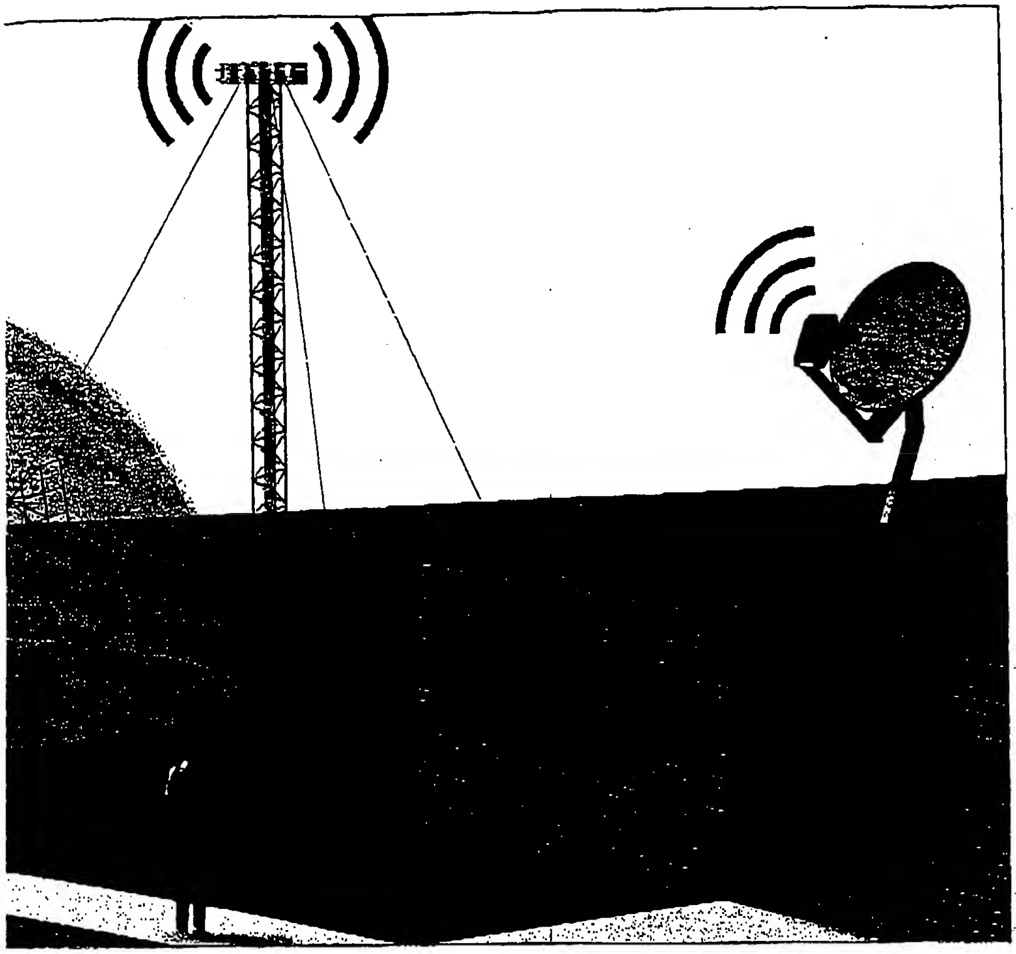
Separating ambient from EUT emissions however, only solves part of the problem. You still need to find the offending emission source. If there are several unrelated emitters, all generating the same frequency, which one is the culprit? A spectrum analyzer will point to the emitter with the highest signal amplitude, but that may not be the source of the problem.



CASSPER's source localization capability can pinpoint emission sources among several unrelated emitters operating at the same frequency.

ources, With One Easy To Use System:

1



Technology and urbanization increases RF ambient noise, interfering with EMC measurements. The CASSPER system uses ambient cancellation to create a "virtual chamber" for testing.

The Solution

CASSPER® (Configurable Automated System for Sensing and Processing Electromagnetic Radiation) is a breakthrough system that performs fast, accurate RF emission testing, even in the presence of ambient radiators. It creates a Virtual Chamber™ environment for pre-compliance measurements and EMI troubleshooting. The result? Test sites overrun with ambient can be used again, in-place testing can be performed on the factory floor without interruptions for equipment shutdowns, and hard to identify radiation sources can be located with pinpoint accuracy.

(1)

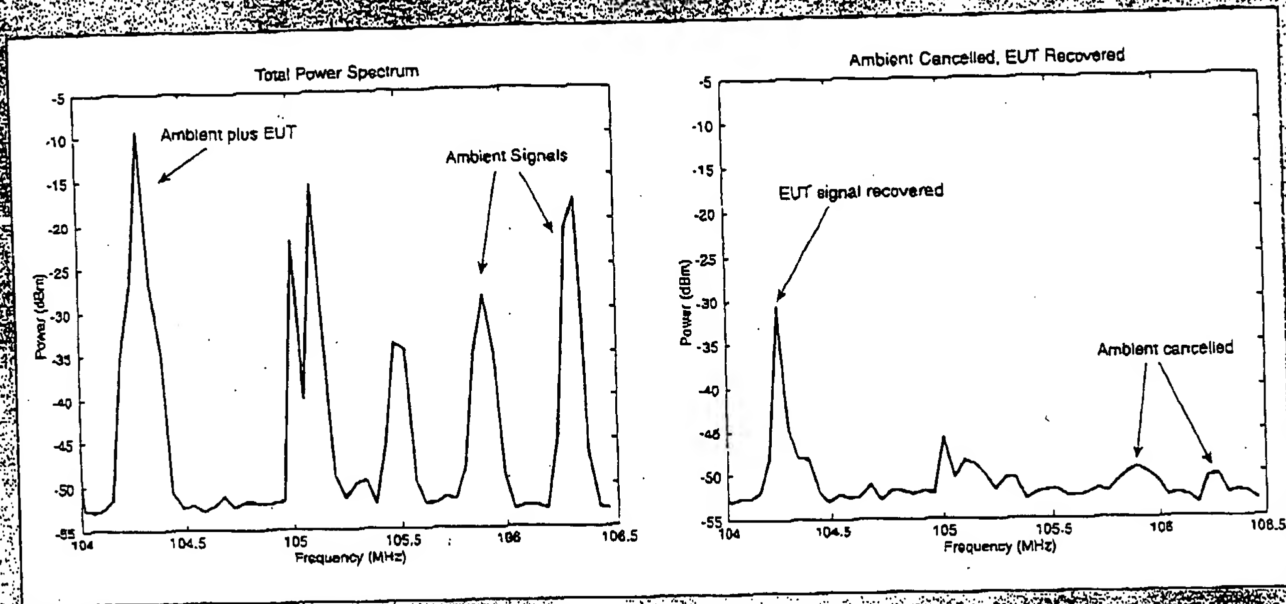
What is CASSPER?

CASSPER is an integrated system that combines Windows® and LabVIEW®- based software with a powerful PC, high-speed digital signal processors (DSP), and a unique, frequency-synchronized, phase-locked, dual-channel, multi-port receiver. The CASSPER receiver uses two time and frequency-synchronized channels to simultaneously record signals at multiple locations. High speed digital signal processing allows CASSPER to cancel interfering ambient signals, accurately estimate EUT signal strengths, and relate radiating emission signals to their sources.

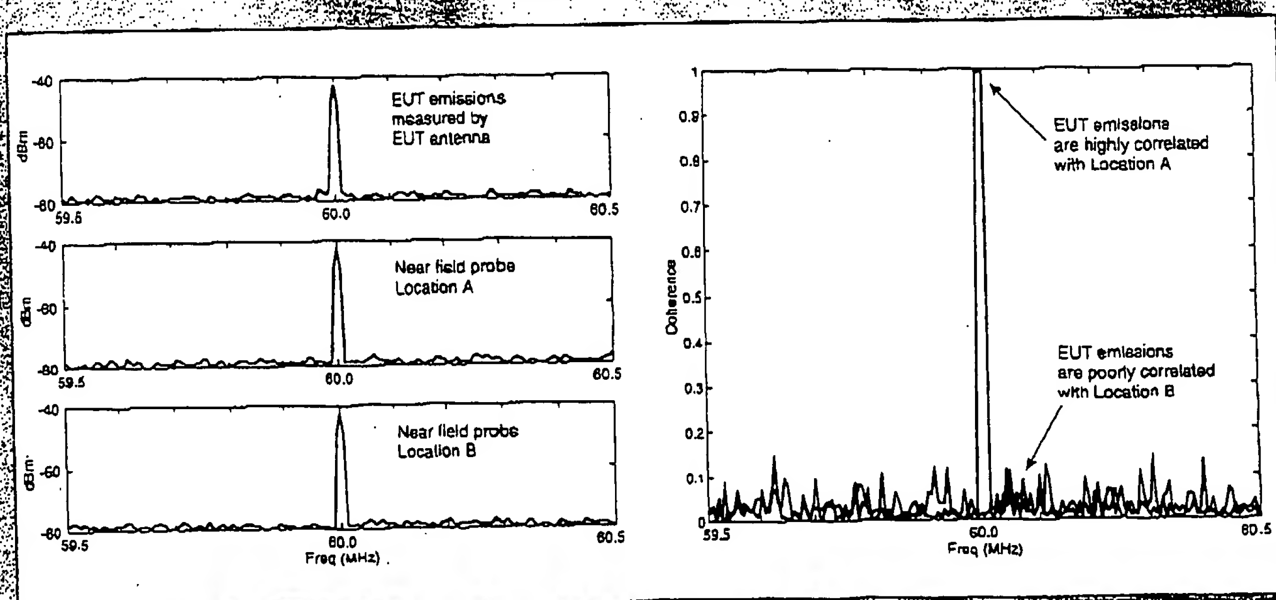
Each of the two channels (A and B) has up to four ports on the front of the receiver for sensor input. Multiple sensors can be connected, with automatic port switching based on the operating frequency of the sensor(s).

Before measurements begin, files are created describing the sensors being used and their related data (antenna factor, transfer impedance, insertion loss, etc.). A minimum of two sensors, one for each channel, is used. For ambient cancellation, one sensor measures both EUT and ambient radiation while the other measures ambient radiation. For source localization, one sensor measures the problem signal and the other sensor probes for its origin. The EUT and ambient signals can be CW, AM, FM, or digitally modulated.

1



Traditional instrumentation only displays frequency and amplitude. CASSPER cancels the ambient and recovers the EUT signal.



(1)

Applications: Ambient Cancellation

Like most test setups, an antenna is placed at a distance *d* in front of the EUT. This antenna is connected to Channel A and receives both EUT and ambient emissions. A second antenna is placed further away at a distance of approximately ten times *d*. This reference antenna records the total ambient and is connected to Channel B. Both antennas are placed in the same direction and polarization.

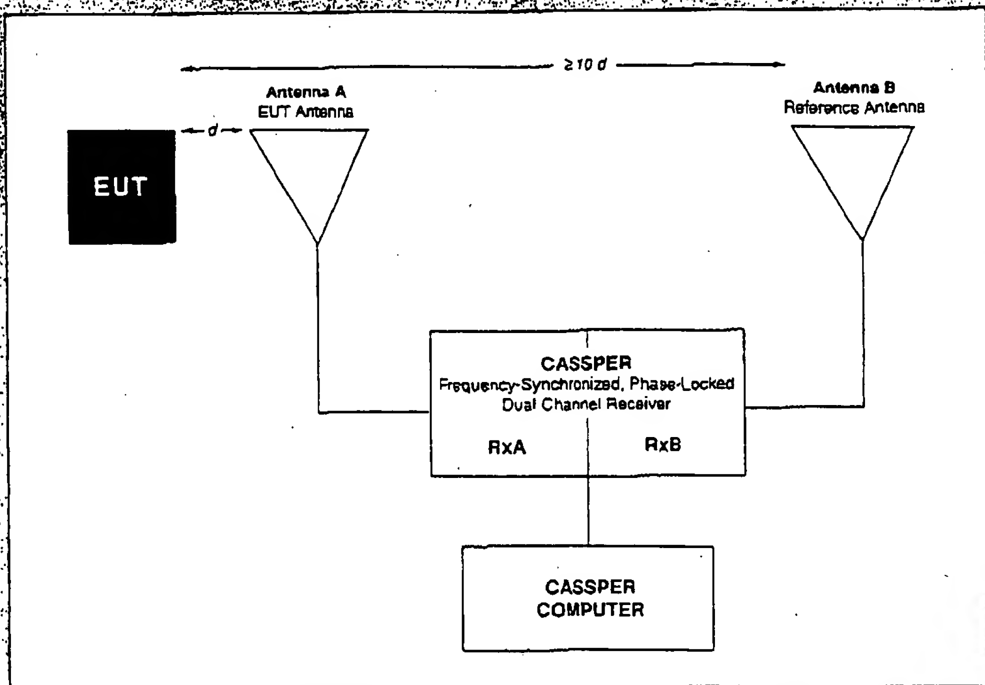
CASSPER's receiver channels are time and frequency-synchronized, simultaneously recording the radiated field strength at the two locations. The correlated ambient signals from the two received time series are cancelled, creating a virtual third measurement channel. This measurement contains signals unique to Channel A, and represents the EUT.

CASSPER provides several control functions for Ambient Cancellation mode:

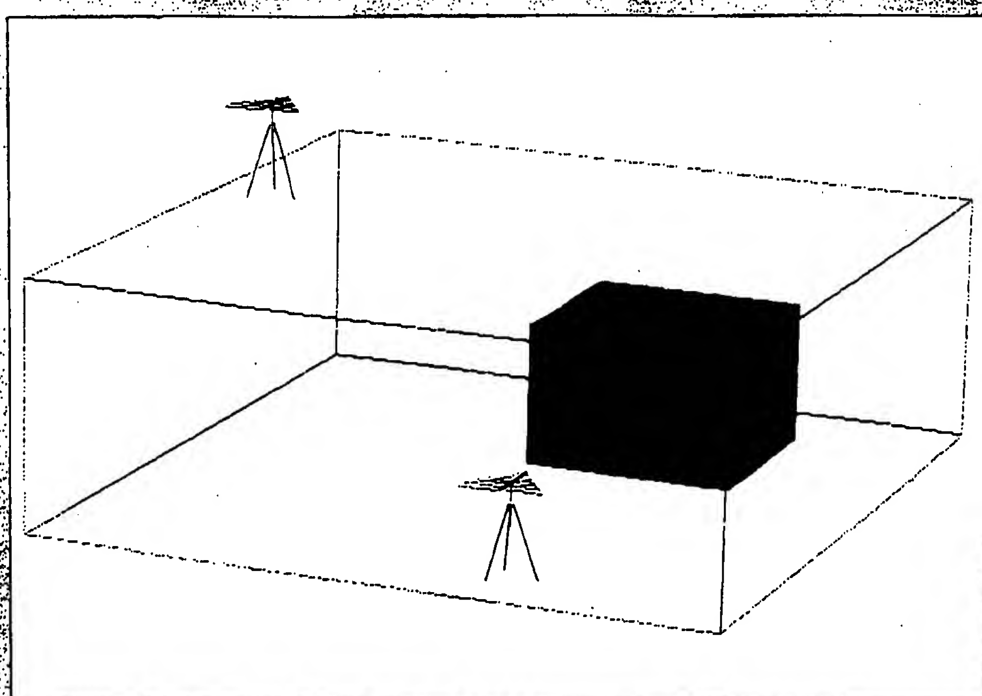
- Automatic port switching between multiple sensors to accommodate band breaks
- Selectable limit levels for FCC and CISPR measurements
- Peak, Quasi-Peak, Average detection (Q-P & Avg. options avail. in '00)
- Single or continuous-sweep scan method
- Selectable bandwidth resolution
- Threshold—cancellation only performed on signals above a specified limit line
- Safety Factor—cancellation performed on signals within or above *n* dB of the current limit line
- Suspect Table—automatically generated list of data points equal to or exceeding the current limit line
- Graph Legend, Graph Marker
- Data export function to Word and Excel files

(C)

Typical Ambient Cancellation Setup



Block Diagram



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Applications: Emissions Source Localization

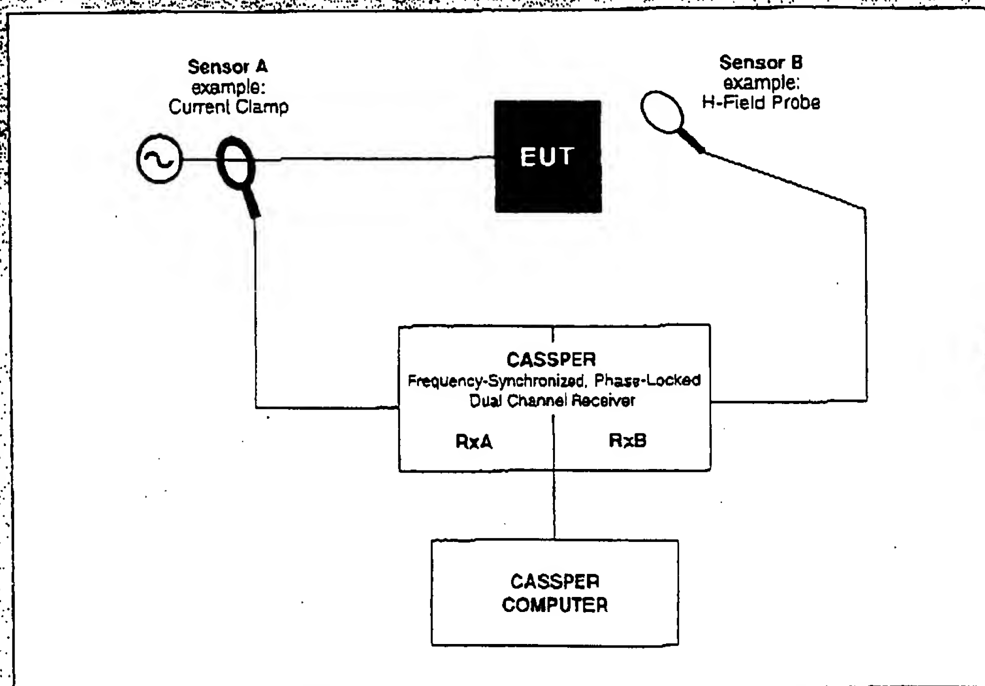
To perform source localization, the EUT antenna used for the ambient cancellation test setup can remain in the same position, connected to Channel A, receiving both EUT and ambient emissions. For board level testing, the EUT antenna can be replaced with another sensor such as a current clamp, and the reference antenna connected to Channel B can be replaced with an E or H near-field probe. However, in-place testing of a large EUT may be more practical if two antennas are used instead. Either way, the choice and location of sensors are not as important as they are for ambient cancellation.

CASSPER's receiver channels are time and frequency-synchronized, simultaneously recording the field strength at the two locations. The phase relationships between the two signals are measured, and a coherence value of 0 to 1 is determined. A coherence value of 1 indicates that the two signals are related and are from the same source, pinpointing the emissions source. This remains true even if it is one of several emitters radiating at the same frequency and amplitude. This information, and the ability to easily determine the culprit source, cannot be gathered using traditional instrumentation.

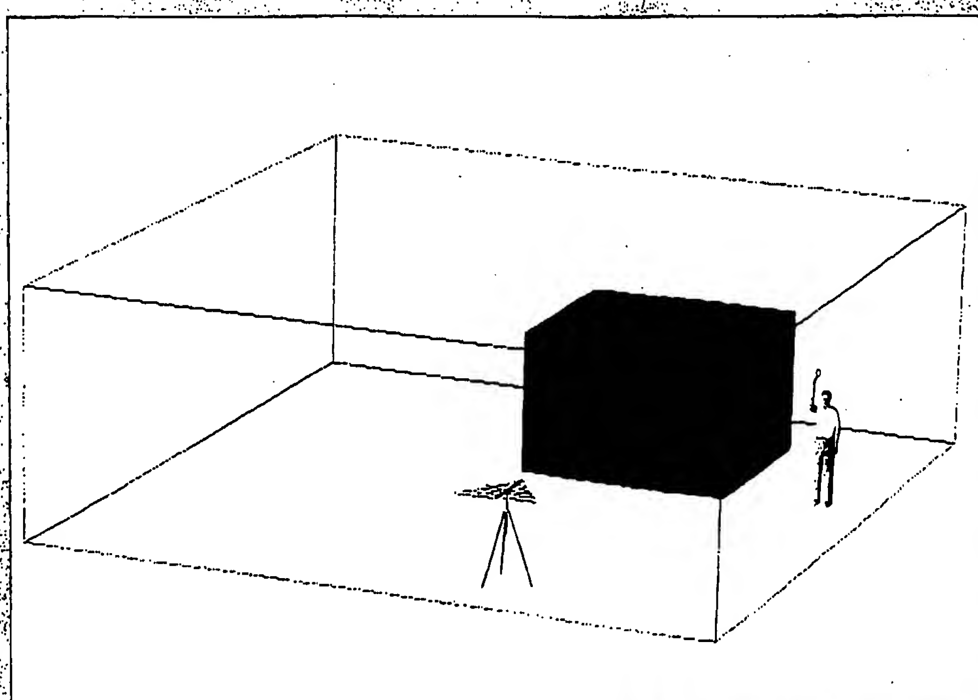
CASSPER provides several control functions for Emissions Source Localization mode:

- Automatic port switching between multiple sensors to accommodate band breaks
- Single or continuous-sweep scan method
- Selectable bandwidth resolution
- Averaging—selectable data sampling rate
- Rx B Filter—selectable Coherence Threshold
- Suspect Table—automatically generated list of data points equal to or exceeding the Coherence Threshold
- Graph Legend, Graph Marker
- Data export function to Word and Excel files

Typical Emissions Source Localization Setup



Block Diagram



(1)

Practical Applications:
EMC and Electronic Design Engineers

- Performing pre-compliance emissions testing
- Performing in-place testing for large systems and assemblies
- Performing on-site testing
- Making RF noisy test sites useable again
- Relieving backlog from over-scheduled test resources
- Qualifying designs for potential emissions problems
- Performing A/B comparisons
- Qualifying incoming components and assemblies
- Performing post-production sample testing

CASSPER vs. Traditional Source Identification Methods

	CASSPER	Traditional Source Identification
System Tools	• Power Spectrum Measurement • Ambient Cancellation • Source Localization	• Power Spectrum Measurement
Operator Expertise Required	Technician	EMC Expert
Time Required	< 1/2	1-3 days
Cost	≈ $50k	$100-500k

Putting CASSPER to Work for You!

CASSPER is an intuitive, powerful system that extends existing resources and opens up tremendous new possibilities. Request a demonstration at your facility now, and see what CASSPER can do for you! Visit our website for the location of your local distributor.

3

Evaluation Engineering

Readers' Choice

CASSPER EMI Test System
EMC Test Systems

The CASSPER EMI Test System records and isolates EUT signals without the need for anechoic chambers. It delivers true ambient cancellation. The modular and portable PC-based instrumentation system features coherence measurement to identify and locate sources of EMI noise, including multiple sources of the same frequency. This is achieved by comparing a near field probe's signal to the radiation received by the EUT test antenna.

EMC Test Systems
(512) 835-4684

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The Web's First Defi

Product of the Week

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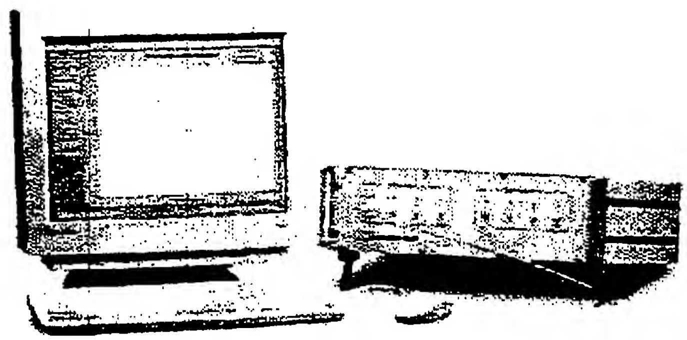
New Departures

PC-Based EMI Tool Can Ease RF-Compliance Measurements



The manufacturer says . . .	Chipcenter's Alex Mendelsohn says . . .
CASSPER records and isolates EUT signals of interest without the need for anechoic chambers Lake Forest, CA and Austin, TX–CASSPER Instrumentation Systems, Inc. (CIS) and EMC Test Systems (ETS) announced an investment and distribution agreement focused on developing the American and European markets for CASSPER system for EMC Testing. ETS has taken an equity interest in CIS and will put its distribution and marketing resources behind the new product. CASSPER is a new PC-based instrumentation system that records and isolates EUT (equipment under test) signals of interest without the need for anechoic chambers. The system delivers true ambient cancellation and removes the guesswork in signal identification. The product's coherence measurement feature allows engineers to identify and locate sources of EMI noise, including multiple sources of the same frequency. This saves enormous engineering time during the mitigation stage at the board, unit or system level. The system is modular and portable, so it can be easily	First off, let's define the acronym. CASSPER stands for *Configurable Automated System for Sensing and Processing Electromagnetic Radiation* . Now that we know that, just what is CASSPER, and why might it be the answer to an RF engineer's prayers? If you're working with sensitive receivers and associated transmitters, you need to know where you stand with respect to electromagnetic compatibility (EMC) and electromagnetic interference (EMI). Indeed, the CASSPER system promises to be a reasonable way to get the proverbial "leg up" when it comes to pre-compliance emissions testing. But wait, there's more. If you use this reasonably priced instrument (it costs about $45,500 to $47,000, depending on configuration; probes and antennas are options), you'll be in a position to know where you stand *before* you undergo FCC test stints. Moreover, the unit's price tag is about half what you'd expect to pay for a conventional test setup. That means you can test to your heart's content prior to spending the big bucks at an FCC lab.

configured to meet a variety of specific needs.

"The product gives engineers far more tools than ever before. Ambient cancellation and source localization are now available to anyone - even in the lab or on the production floor," explains Stephen Watkins, President of CIS. "ETS is a leader in the EMC test market, and they recognize the tremendous potential for this product. We're very excited about the prospects for this union."

Bruce Butler, VP and General Manager of ETS stated that "we are convinced that CASSPER will have a tremendous impact on the market. 'Encroaching urbanization' is a trend that will continue to impact our customers' ability to test—and this product solves the problem."

ETS is a manufacturer of products that measure, contain and suppress electromagnetic RF and microwave energy. The company markets its products under the brand names of Rantec, EMCO, Ray Proof (North America) and Euroshield.

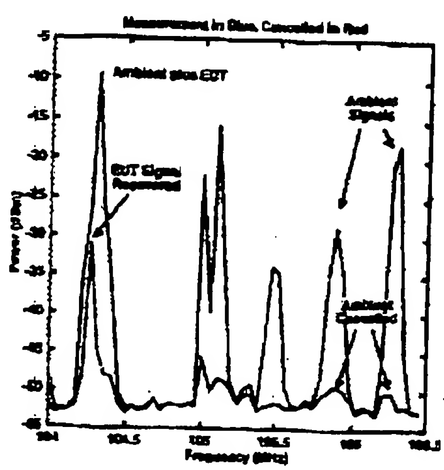
CASSPER Instrumentation Systems, Inc. focuses on the design, manufacture, sales and support of innovative systems to help manufacturers of electrical equipment measure EMI (electromagnetic interference) and determine compliance with regulations of the FCC and similar governmental organizations around the world. The company's products were developed and proven under contract to the United States Air Force.

bucks at an FCC lab.

New Departures
By Alex Mendelsohn

Why not use a conventional spectrum analyzer? After all, isn't that what most RF engineers turn to when they need to get a handle on what's happening in the frequency domain? True enough, but what about signals that are hidden by external RF noise?

In many outdoor radiated-emissions test sites, ambient RF levels are often above the emissions limits you're looking for. Radio and TV broadcast signals can be 30 dB or even 40 dB above radiated emissions limits in some urban locations. Just run your spectrum analyzer with a short antenna on its input if you want to see those signals.



CASSPER takes a different tack, using the power of DSP. It identifies RF emitters (not just for frequency and power level), in spite of ambient RF noise--and without a pricey anechoic range chamber. It can also let you readily perform A/B comparisons over a range from 200 Hz all the way up to 1 GHz.

Hard-to-identify radiation sources can also be located with pinpoint accuracy. Imagine being able to zero in on a leaky cable, or a harmonic-laden clock line, or a nearby transmitter that's emitting a spurious signal.

Thanks to it being PC-hosted and small in size, a CASSPER system can be sited conveniently at various points in your enterprise or in the field. As such, it seems like a natural for incoming component and subassembly qualification testing. You can run your RF tests on-site if the system you're developing isn't in your lab, or doesn't fit in your lab, or in an anechoic chamber, for that matter.

Your manufacturing technicians can just as readily use it in post-production sample testing. Little special test expertise is required.

The CASSPER box also promises to relieve backlogs from over-scheduled test resources. Moreover, while chamber-bound third party test sessions typically demand as many as three days to come up with results, the little CASSPER can usually do the same tests and come up with meaningful results in half a day or so.

The Virtual Chamber

In the past, one way around the ambient hash and noise problem was to perform your compliance or RFI tests in a remote area, or inside an expensive, and oftentimes large, shielded anechoic chamber or screen room. Now you enter what CIS/ETC calls a Virtual Chamber.

Indeed, the Virtual Chamber is the beauty of the CASSPER system. You can run accurate RF emission tests, even in the presence of annoying ambient signals in the spectrum of interest. Ambient cancellation is the secret.

In fact, you can now make measurements at test sites that have been proven to be overrun with ambient signals. That means in-place testing can even be performed on the factory floor, for example, or in other previously unsuitable locations.

Windows and LabVIEW

The key to making this happen, in part, is CASSPER's use of a point-and-click Microsoft Windows environment running National Instruments' popular LabVIEW software. The CASSPER system uses these PC-hosted applications, along with DSP hardware, in a frequency-synchronized phase-locked multi-port receiver.

The dual-channel receiver's time- and frequency-synchronized channels can simultaneously record signals at multiple locations. The box's high-speed DSP then cancels interfering ambient signals, while accurately estimating EUT signal strengths. Moreover, the system relates radiating signals to their sources. That's pretty neat.

In use, multiple sensors (antennas or perhaps current transformers) are patched to CASSPER's hardware enclosure, with automatic port multiplexing based on the operating frequency of the sensors. Each of the system's two channels (A and B) has up to four front panel 50-ohm input ports. At minimum, you'd connect two sensors, one for each channel. For ambient cancellation, one sensor measures both EUT and ambient radiation, while the other measures ambient radiation.

Prior to actually making any measurements, the system creates files describing the sensors you've chosen. It also stores related data, such as antenna factors, transfer impedance, and insertion loss metrics.

For source localization, one sensor measures the problem signal and the other probes for its origin. The EUT and ambient signals can be CW, or AM or FM, or digitally modulated. Regardless of signal type, CASSPER cancels the ambient signals and recovers the EUT signal. Even multipath distortion won't phase the CASSPER (no pun intended).

In some cases, two signals that have the same frequency aren't necessarily related. They may (or may not) be from the same source. No problem for CASSPER. It can localize RF sources by identifying measurements that *are* related and from the same source.

If you use CASSPER for ambient cancellation, an antenna is placed at some distance *d* in front of your EUT. The antenna is then connected to Channel A. Naturally, it receives both EUT and ambient emissions. However, a second antenna is also placed further away--at a distance of approximately ten times *d*. This becomes your reference antenna; it's connected to Channel B. It records the total ambient signal content. By the way, both antennas are generally pointing in the same direction and have the same polarization.

CASSPER's time- and frequency-synchronized receive channels simultaneously record the radiated field strength at the two locations. The correlated ambient signals from the two received time series are then canceled, creating a virtual third measurement channel. This measurement contains signals unique to Channel A, and therefore represents the EUT.

If you use the system to perform source localization, the EUT antenna used for the ambient cancellation test setup can remain in the same position, connected to Channel A, receiving both EUT and ambient emissions. For board-level testing, the EUT antenna can be replaced with a sensor such as a current clamp, and the reference antenna connected to Channel B can be replaced with an *E* or *H* near-field probe.

However, in-place testing of a large EUT may be more practical if two antennas are used instead. Either way, the choice and location of sensors are not as important as they are for ambient cancellation.

CASSPER also provides several nice control functions for its Ambient Cancellation mode. Automatic port switching between multiple sensors, for example, accommodates band breaks. The system also lets you select limit levels; that's useful when making FCC and CISPR measurements where threshold-cancellation is only performed on signals above a specified limit line.

You can also operate the system in peak, quasi-peak, or average detection modes. CASSPER can also run single or continuous-sweep scans, and with selectable bandwidth resolution.

The Usual Suspects

The system can also automatically create what CIS/ETS dubs a Suspect Table. It's a generated list of data points that are equal to, or exceed, a current limit line. The system also offers graph legend and graph markers, and packs a useful data export function that will let you port your gathered data to Word files and Excel spreadsheets.

Because CASSPER's receiver channels are time- and frequency-synchronized, the system simultaneously records the field strength at the two locations. Phase relationships between the two signals can be measured, and a coherence value of 0 to 1 can be assigned.

A coherence value of 1 would indicate that the two signals are related and are from the same source, pinpointing the emissions source. This remains true even if it's one of several emitters radiating at the same frequency and amplitude. This kind of information, and the ability to actually determine the culprit source, can't usually be gathered using conventional instrumentation. It puts the CASSPER in a class by itself.

Back to Top

3

Evaluation Engineering

Return to home page

Eight Products Win Honors From Readers

EE Evaluation Engineering READERS' CHOICE 1999

1999 was a great year for new product introductions. Of the hundreds of products that debuted on the market, which ones stand out as tops in their class? To find the answer, we turned to our readers. We asked you to select the products you considered as outstanding introductions last year. You cast your votes on our web site and responded to our e-mails. We counted all the replies and here are the results of **EE**'s seventh annual **Readers' Choice Awards**.

This year, the selection was divided into eight categories: **ATE, Instrumentation, Data Acquisition, Software, EMC, ESD, Communications Test, and Environmental Test**. The ballots were completed via the **EE** web site and e-mail solicitations, and the competition was keen. To see a photo and more information, click on the product names below.

AUTOMATED TEST EQUIPMENT

The winner in the ATE category is the Agilent Technologies' **HP 93000 SOC Series** that performs volume production test on system-on-a-chip devices. It is available in pay-per-use and fixed configurations and both models support test heads with up to 448 or 960 digital pins and space for up to four analog modules.

INSTRUMENTATION

For instrumentation, the award goes to the **TDS3000** family of two- and four-channel color digital phosphor oscilloscopes from Tektronix. Six DPO models with 10-kword memories are offered. Bandwidth and sample-rate combinations are 100 MHz, 1.25 GS/s; 300 MHz, 2.5 GS/s; and 500 MHz, 5 GS/s.

DATA ACQUISITION

IOtech's DaqBoard/2000™ takes top honors in the Data Acquisition voting. This multifunction plug-and-play PCI board features 200-kHz A/D; 100% digital calibration; bus mastering; dual 16-bit, 100-kHz D/As; 40 digital I/O lines; four counters; and two timers. Software support includes drivers and tools for most programming environments under Windows 95/98/2000/NT.

3

SOFTWARE

When it comes to new software, the honors go to **LabVIEW 5.1** from National Instruments. Version 5.1 with 3-D graph control to enhance modeling and visualization, streamlines the creation of web-enabled applications. Using new built-in tools, VI front panels can be published on web pages with no programming required.

EMC

Your choice for the best EMC product in 1999 is the **CASSPER EMI Test System** from EMC Test Systems. The modular and portable PC-based instrumentation system records and isolates EUT signals without the need for anechoic chambers. It also delivers true ambient cancellation.

ESD

The **Model 960 Mini Air Ionizer** from the 3M Electronic Handling and Protection Division is the winning ESD product. The Model 960 features steady-state DC ion emission and balanced shielded emitter points that do not require any adjustments. It is UL/C-UL/CE marked for global acceptance.

COMMUNICATIONS TEST

In Communications Test, the award goes to Tektronix for the **Q7750 Optical Network Analyzer**. The Q7750 provides amplitude, chromatic dispersion, and group-delay measurements for fiber-optic systems. It collects and presents 600 data points in 4 s and operates in the 1,530-nm to 1,600-nm wavelength range.

ENVIRONMENTAL TEST

Environmental Test honors are presented to **JAGUAR**, a workstation-based, distributed-process solution for structural, acoustic, and closed-loop vibration control from Spectral Dynamics. The JAGUAR controls the shaker tables that simulate vibration stress, takes measurements from the object under test, and displays results such as transfer functions and power spectral densities in real-time.

For all of our readers who took time from your very busy schedules to vote for the 1999 Readers' Choice Awards, we thank you.

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Innovative Pre-Compliance Test Methodology Using Ambient Cancellation and Coherence Detection Techniques

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Abstract

An innovative pre-compliance test methodology is introduced which enables accurate and rapid radiation emission testing in the presence of strong interfering ambient radiators. The methodology is based on a test technique which uses time and frequency synchronized multi-channel receiver systems to simultaneously record total fields at multiple locations. Advanced signal processing is used to cancel interfering ambient signals, accurately estimate the EUT signal strengths, and relate radiation emission signals to their origins.

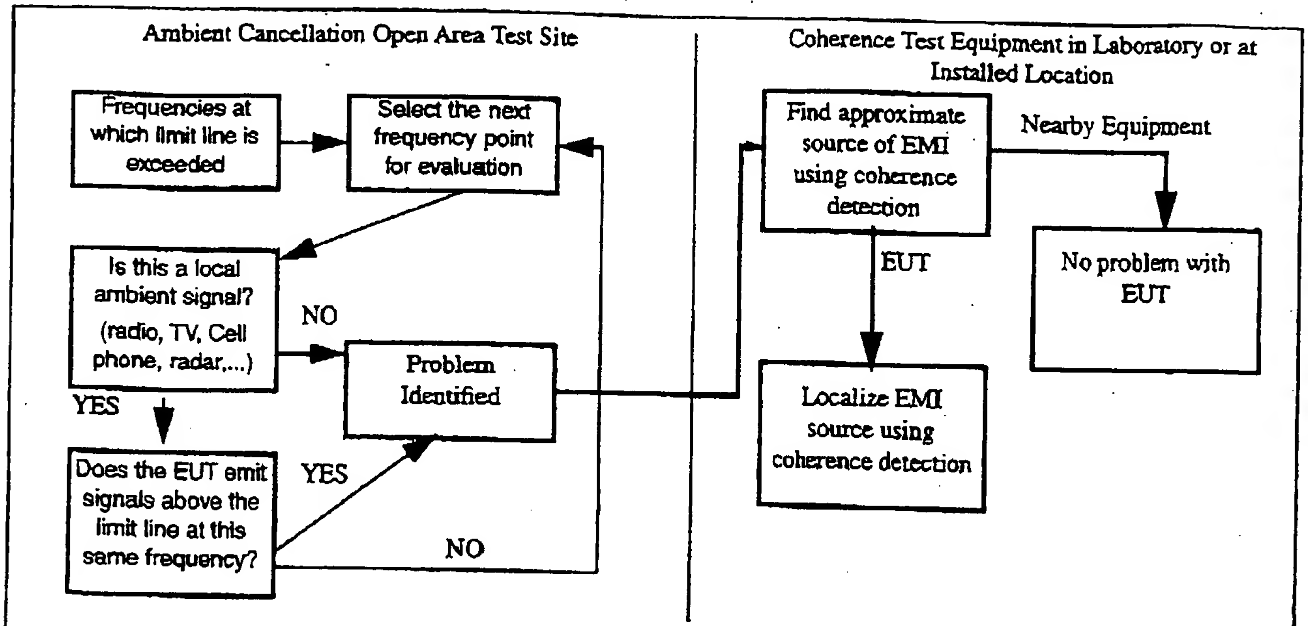

Figure 1. **Pre-Compliance Test Methodology Flow Diagram. This methodology uses both ambient cancellation and coherence detection techniques to identify the level of compliance and the source of potential problems.**

The presented test methodology virtually eliminates the need for expensive anechoic chambers for pre-compliance testing and EMI troubleshooting. As a result, low cost and automated pre-compliance testing can be effectively conducted in Open Area Test Sites (OATS) or inside fully operational plants throughout the product development cycle.

Radiation Emission Measurement Challenge

Historically, radiation emission measurements in an open environment or within an operational environment have been difficult or generally impossible because of ambient noise sources contaminating the measurements. The solution currently used for pre-compliance testing or EMI trouble shooting is to place the EUT in an anechoic chamber to conduct tests. While this may be acceptable from a technical perspective, the user finds that the tests are expensive and difficult once the equipment is installed in the field. The current solution is also limited by its inability to easily and conclusively identify sources of excessive radiated signals.

The test methodology introduced by this article utilizes two unique capabilities of an instrumentation system (Virtual Chamber™) that has been developed and demonstrated for radiation emission applications. The two phase process is illustrated in Figure 1.

The first phase is to determine if a radiation problem exists and at which frequencies. Typically, in an open or operational environment, the power spectrum density at many frequencies (typically dozens) will exceed the radiation emission specification. For each of these potentially troublesome frequencies, the challenge is to answer the following questions:

- Is the signal due to external ambient signals, and
- Does the EUT have excessive internally-generated signals at the same frequency but hidden by the external ambient signal?

These questions are answered, in an open environment or in the operational environment, using the ambient cancellation techniques of the instrumentation (Virtual Chamber™) system.

The second phase, assuming excessive radiated signals have been identified, is to locate the precise source of the signals. This is accomplished using the coherence detection aspects of the system.

The remaining portions of the article describe each of the two features of the system in more detail.

Ambient Noise Cancellation

Radiation emission testing in noisy urban environment is a challenge complicated by the presence of numerous ambient man-made radiators whose field strengths can be 10s of dB above the certification limit lines. Emissions from the equipment under test (EUT) at these ambient frequencies cannot be detected since they are masked by the much higher amplitude of the ambient

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signals. To circumvent this problem, radiation emission tests are either conducted in anechoic chambers or at remote outdoor test sites. These test facilities are expensive to setup, maintain, and operate and are out of the reach of most small electronic equipment manufacturers.

In order to successfully measure emissions in an outdoor urban environment, the undesired ambient signals will have to be removed or cancelled from the total field measurements. Earlier attempts to achieve ambient cancellation consisted of subtracting the power spectral densities measured by two received channels, one located near the EUT and the other far from the EUT. This technique failed since traditional Spectrum Analyzers do not record the detailed phase variation of the signals and only report the power spectral density averaged over a specified time slice.

A robust ambient cancellation instrumentation system (Virtual Chamber™) has been developed and demonstrated for radiation emission applications consisting of the following steps:

- Two simultaneous receiver channels, one channel near the EUT and a reference channel far from the EUT are used (see Figure 2). The first channel records the EUT emission plus the ambient signals, and the reference channel only records the ambient signal.

- The two receiver channels are time and frequency synchronized and record the radiated field strength at the two specified locations for further processing.

- Advanced digital signal processing techniques are used to cancel the correlated ambient signals from the two received time series. The residual is the recovered EUT field strength which, in turn, is used to generate the EUT's power density spectral function (see Figure 3).

The primary assumption for this procedure is that the ambient signal time series data received at the two physically separated receiver channels are correlated. To ensure this condition, the reference channel needs to be free of various reflections (such as reflections from the ground and nearby structures). Once the reference channel is reflection free, then it becomes correlated with the ambient signal received by the EUT channel — no matter how many reflections it may have.

Figure 3 shows a typical ambient cancellation result achieved in SARA's parking lot located in Huntington Beach, California. The reference antenna consisted of a monopole located on a ground plane about 100 feet away from the EUT. The EUT was simulated by a

signal generator connected to a bi-log antenna. The EUT receive channel was located about 6 feet from the simulated EUT. Note the excellent cancellation of all ambient signals which happen to be the strong local FM stations. The signal generator was used to simulate the EUT signal at different frequencies and amplitude. The Virtual Chamber consistently recovered the EUT signal in all cases within ±2 dB accuracy and was able to cancel the strong ambient signals by as much as 50 dB.

The Virtual Chamber system has also been successfully tested in indoor environments (such as inside a building or on factory floors) and yielded similar cancellation performance. For optimal indoor applications, the reference antenna must be located outside the building so it can receive the ambient signal with minimal reflections. The Virtual Chamber system presented here is for pre-compliance use and is not CISPR-16 qualified. The fully compliant system is capable of accurately measuring EUT EM emission signals even when emitted signals are masked by much stronger ambient signals. This is accomplished by simultaneously measuring the field strength at two physically separated locations and canceling the ambient signals received at the two synchronized receiver channels using advanced signal processing algorithms (Patent Pending). The system is currently capable of up to .50dB of ambient cancellation which is adequate for most urban outdoor radiated emission test applications.

Fault Detection & Isolation

Most EMI problems can be broken down into the following three parts:

1. The source of the harmful EMI noise,

2. The EMI coupling mechanism, and

3. The receptor or victim.

For a radiated emission problem, two of the three items are generally known. The EMI coupling mechanism is through air and the EMI receptor is at the measuring antenna or current probe. Unfortunately, determination of the remaining part, the actual EMI source, is often complicated by the presence of multiple sources or their harmonics which happen to be at the same frequency of interest. Identification of the harmful EMI source from several similar EM emission sources is the time consuming challenge faced by EMC engineers.

A real-time digital signal processing technique has been developed and demonstrated to make this problem solving process more efficient. This technique takes advantage of the phase as well as the amplitude of the measured source and receptor signals. It uses correlation algorithms to process the two simultaneous measurement signals and estimate a critical parameter called the *Coherence* factor. The Coherence factor clearly identifies whether two measurements having the same frequency content are related or not. If they are perfectly related, the Coherence factor will be one. If they are perfectly uncorrelated, then the Coherence factor will be zero. This technique allows the EMC engineer to quickly identify and isolate the dominant source of the EMI noise. An important advantage of this technique is that the system under test does not have to be turned off and on. This article presents the technical approach used as well as two successful real world applications of this technique.

The first application was at a gas station/convenience store experiencing intermittent immunity problems suspected to be caused by nearby police/fire VHF/UHF transmissions. These ambient signals were thought to be interfering with the POS terminals at this site. With the aid of the Coherence factor, the VHF/UHF signals were quickly tracked down. After further investigation, it was determined that the interference was caused by a bad computer cable shield and a local ground loop problem and not the local ambient signals.

The second application was at a large semiconductor equipment manufactur-

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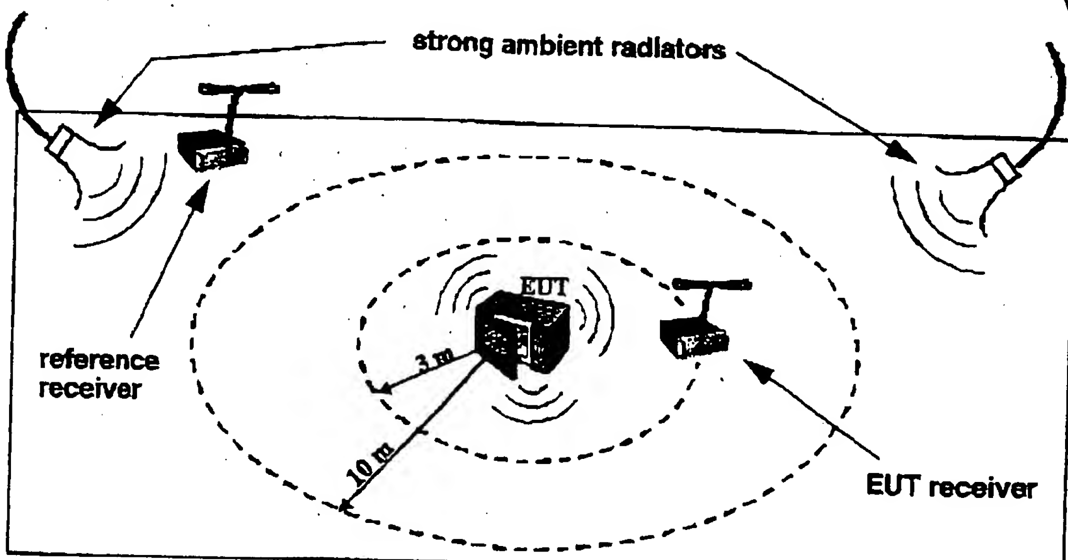

Figure 2. **Ambient Cancellation Setup.** Two time and frequency synchronized receivers are deployed; the first receiver, located far from the EUT, measures the ambient signals; and the second receiver, located near the EUT, measures both the EUT emissions as well as the ambient signals. A central computer compares the two simultaneous measurements and derives the uncorrelated EUT signal.

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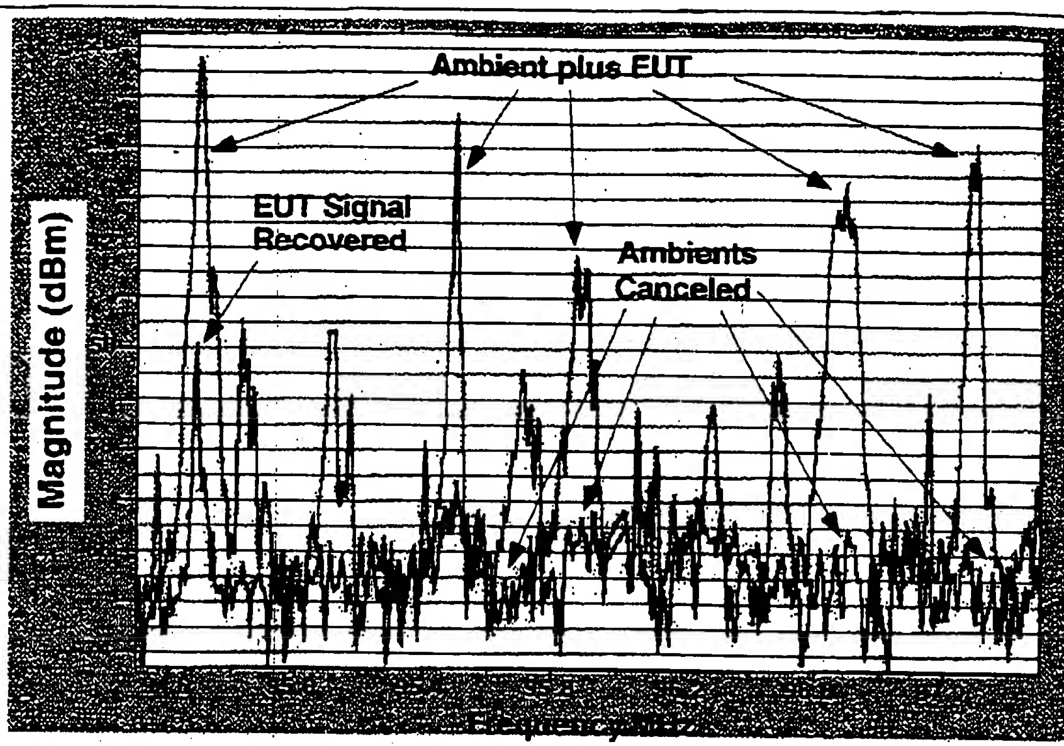

Figure 3. Ambient cancellation in action. Once the ambient signals are canceled, the EUT signal is fully recovered (967 MHz in this example). Note that all ambients without the EUT present have effectively been reduced to the noise floor.

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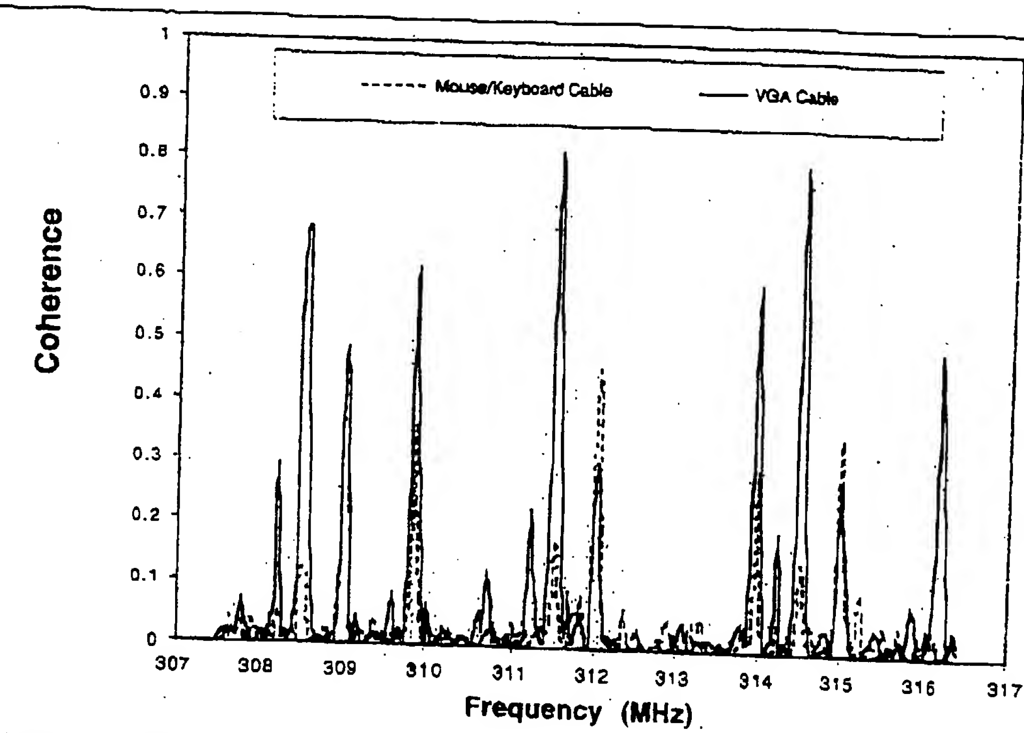

Figure 4. Unlike the power spectral density function displayed by Spectrum Analyzers, the Coherence plot clearly shows the degree of relationship between signals at the same frequency. Note that, in this example, the VGA cable is clearly more related (higher Coherence) to the radiated emission signal than the Mouse/Keyboard cable. This tool, enabled quick identification of the VGA cable as the dominant source of the EMI.

The second application was at a large semiconductor equipment manufacturing plant. A recently developed system had failed radiation emission readings. This complex system had multiple computers and was too large to be moved to an anechoic chamber. The radiation emission readings were further complicated by emissions from other plant equipment which were fully operational during the evaluation process. Using the correlation technique, the EMI source was narrowed down to one of the three computers, and then to the VGA cable on that specific computer, in less than one day. As seen in Figure 4, the Coherence factor clearly indicated that the VGA cable signature was more related to the high radiation emission readings than the mouse/keyboard cable signature. This dramatic conclusion could not have been made from Spectral Power Density measurements of the same two cables.

Conclusion

The technology and test methodology embodied by the Virtual Chamber has been demonstrated to provide a powerful tool for addressing the EM problems frequently encountered by the EMI engineer and small electronic developer. This tool provides for EM radiation and fault isolation testing in the field and in the presence of strong ambient signals. ■

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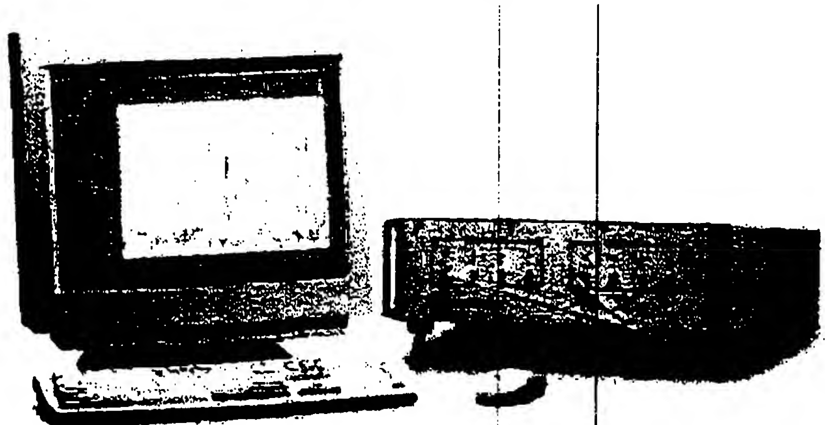
New Departures

HP unveils its new diversified technology company: Agilent Technologies

PC-Based EMI Tool Can Ease RF-Compliance Measurements



The manufacturer says . . .	Chipcenter's Alex Mendelsohn says . . .
CASSPER records and isolates EUT signals of interest without the need for anechoic chambers Lake Forest, CA and Austin, TX--CASSPER Instrumentation Systems, Inc. (CIS) and EMC Test Systems (ETS) announced an investment and distribution agreement focused on developing the American and European markets for CASSPER system for EMC Testing. ETS has taken an equity interest in CIS and will put its distribution and marketing resources behind the new product. CASSPER is a new PC-based instrumentation system that records and isolates EUT (equipment under	First off, let's define the acronym. CASSPER stands for *Configurable Automated System for Sensing and Processing Electromagnetic Radiation*. Now that we know that, just what is CASSPER, and why might it be the answer to an RF engineer's prayers? If you're working with sensitive receivers and associated transmitters, you need to know where you stand with respect to electromagnetic compatibility (EMC) and electromagnetic interference (EMI). Indeed, the CASSPER system promises to be a reasonable way to get the proverbial "leg up" when it comes to pre-compliance

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test) signals of interest without the need for anechoic chambers. The system delivers true ambient cancellation and removes the guesswork in signal identification. The product's coherence measurement feature allows engineers to identify and locate sources of EMI noise, including multiple sources of the same frequency. This saves enormous engineering time during the mitigation stage at the board, unit or system level. The system is modular and portable, so it can be easily configured to meet a variety of specific needs.

"The product gives engineers far more tools than ever before. Ambient cancellation and source localization are now available to anyone - even in the lab or on the production floor," explains Stephen Watkins, President of CIS. "ETS is a leader in the EMC test market, and they recognize the tremendous potential for this product. We're very excited about the prospects for this union."

Bruce Butler, VP and General Manager of ETS stated that "we are convinced that CASSPER will have a tremendous impact on the market. 'Encroaching urbanization' is a trend that will continue to impact our customers' ability to test--and this product solves the problem."

ETS is a manufacturer of products that measure, contain and suppress electromagnetic RF and microwave energy. The company markets its products under the brand names of Rantec, EMCO, Ray Proof (North America) and Euroshield.

CASSPER Instrumentation Systems, Inc. focuses on the design, manufacture, sales and support of innovative systems to help manufacturers of electrical equipment measure EMI (electromagnetic interference) and determine compliance with regulations of the FCC and similar governmental organizations around the world. The company's products were developed and proven under contract to the United States Air Force.

emissions testing. But wait, there's more.

If you use this reasonably priced instrument (it costs about $45,500 to $47,000, depending on configuration; probes and antennas are options), you'll be in a position to know where you stand *before* you undergo FCC test stints. Moreover, the unit's price tag is about half what you'd expect to pay for a conventional test setup. That means you can test to your heart's content prior to spending the big bucks at an FCC lab.

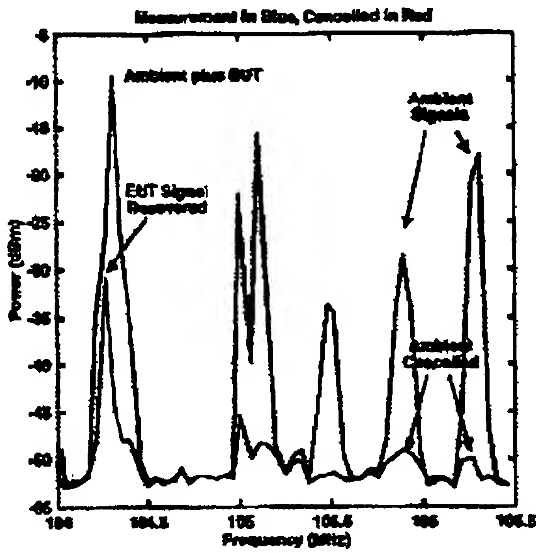
New Departures

By Alex Mendelsohn

4

Why not use a conventional spectrum analyzer? After all, isn't that what most RF engineers turn to when they need to get a handle on what's happening in the frequency domain? True enough, but what about signals that are hidden by external RF noise?

In many outdoor radiated-emissions test sites, ambient RF levels are often above the emissions limits you're looking for. Radio and TV broadcast signals can be 30 dB or even 40 dB above radiated emissions limits in some urban locations. Just run your spectrum analyzer with a short antenna on its input if you want to see those signals.



CASSPER takes a different tack, using the power of DSP. It identifies RF emitters (not just for frequency and power level), in spite of ambient RF noise--and without a pricey anechoic range chamber. It can also let you readily perform A/B comparisons over a range from 200 Hz all the way up to 1 GHz.

Hard-to-identify radiation sources can also be located with pinpoint accuracy. Imagine being able to zero in on a leaky cable, or a harmonic-laden clock line, or a nearby transmitter that's emitting a spurious signal.

Thanks to it being PC-hosted and small in size, a CASSPER system can be sited conveniently at various points in your enterprise or in the field. As such, it seems like a natural for incoming component and subassembly qualification testing. You can run your RF tests on-site if the system you're developing isn't in your lab, or doesn't fit in your lab, or in an anechoic chamber, for that matter.

Your manufacturing technicians can just as readily use it in post-production sample testing. Little special test expertise is required.

The CASSPER box also promises to relieve backlogs from over-scheduled test resources. Moreover, while chamber-bound third party test sessions typically demand as many as three days to come up with results, the little CASSPER can usually do the same tests and come up with meaningful results in half a day or so.

The Virtual Chamber

In the past, one way around the ambient hash and noise problem was to perform your compliance or RFI tests in a remote area, or inside an expensive, and oftentimes large, shielded anechoic chamber or screen room. Now you enter what CIS/ETC calls a Virtual Chamber.

Indeed, the Virtual Chamber is the beauty of the CASSPER system. You can run accurate RF emission tests, even in the presence of annoying ambient signals in the spectrum of interest. Ambient cancellation is the secret.

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In fact, you can now make measurements at test sites that have been proven to be overrun with ambient signals. That means in-place testing can even be performed on the factory floor, for example, or in other previously unsuitable locations.

Windows and LabVIEW

The key to making this happen, in part, is CASSPER's use of a point-and-click Microsoft Windows environment running National Instruments' popular LabVIEW software. The CASSPER system uses these PC-hosted applications, along with DSP hardware, in a frequency-synchronized phase-locked multi-port receiver.

The dual-channel receiver's time- and frequency-synchronized channels can simultaneously record signals at multiple locations. The box's high-speed DSP then cancels interfering ambient signals, while accurately estimating EUT signal strengths. Moreover, the system relates radiating signals to their sources. That's pretty neat.

In use, multiple sensors (antennas or perhaps current transformers) are patched to CASSPER's hardware enclosure, with automatic port multiplexing based on the operating frequency of the sensors. Each of the system's two channels (A and B) has up to four front panel 50-ohm input ports. At minimum, you'd connect two sensors, one for each channel. For ambient cancellation, one sensor measures both EUT and ambient radiation, while the other measures ambient radiation.

Prior to actually making any measurements, the system creates files describing the sensors you've chosen. It also stores related data, such as antenna factors, transfer impedance, and insertion loss metrics.

For source localization, one sensor measures the problem signal and the other probes for its origin. The EUT and ambient signals can be CW, or AM or FM, or digitally modulated. Regardless of signal type, CASSPER cancels the ambient signals and recovers the EUT signal. Even multipath distortion won't phase the CASSPER (no pun intended).

In some cases, two signals that have the same frequency aren't necessarily related. They may (or may not) be from the same source. No problem for CASSPER. It can localize RF sources by identifying measurements that *are* related and from the same source.

If you use CASSPER for ambient cancellation, an antenna is placed at some distance *d* in front of your EUT. The antenna is then connected to Channel A. Naturally, it receives both EUT and ambient emissions. However, a second antenna is also placed further away--at a distance of approximately ten times *d*. This becomes your reference antenna; it's connected to Channel B. It records the total ambient signal content. By the way, both antennas are generally pointing in the same direction and have the same polarization.

CASSPER's time- and frequency-synchronized receive channels simultaneously record the radiated field strength at the two locations. The correlated ambient signals from the two received time series are then canceled, creating a virtual third measurement channel. This measurement contains signals unique to Channel A, and therefore represents the EUT.

If you use the system to perform source localization, the EUT antenna used for the ambient cancellation test setup can remain in the same position, connected to Channel A, receiving both EUT and ambient emissions. For board-level testing, the EUT antenna can be replaced with a sensor such as a current clamp, and the reference antenna connected to Channel B can be replaced with an *E* or *H* near-field probe.

However, in-place testing of a large EUT may be more practical if two antennas are used instead. Either way, the choice and location of sensors are not as important as they are for ambient cancellation.

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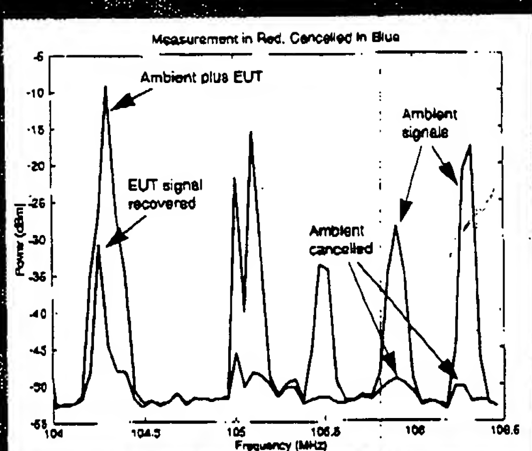
Tired of fighting through the ambient to find your product's emissions?

Does a conventional chamber seem expensive?

Try The Virtual Chamber™ for EMC testing



True ambient cancellation

Emissions source localization

Regulatory pre-compliance

Modular, portable PC-based instrumentation system

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2

CASSPER™

Regulatory Pre-Compliance Application

Will Ambient Cancellation & Fault Detection Capabilities

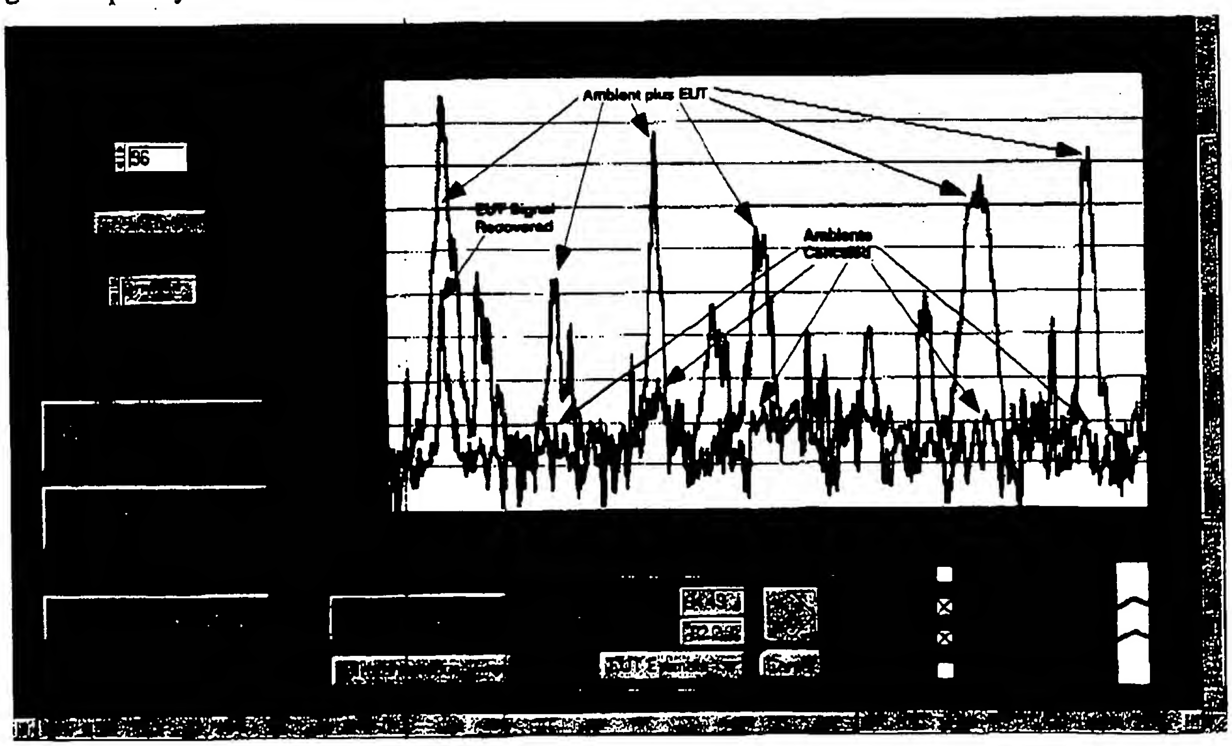
*Transform your outdoor test range into a complete "regulatory pre-compliance" emissions test facility. Only the **Patent Pending** CASSPER® can eliminate your troublesome ambient signals and "pull out" the desired EUT signal. The same product can be used to pin point the source of any detected EMI signals which exceed the limit lines.*

Complete Regulatory Emission Package:

- General emission capability
- Preset test configurations for ITE, Test and Measurement, Medical and others for both radiated and conducted emissions
- Unlimited marker capability
- Save/replay capability for data comparison
- Technician notes saved with data files
- Integration with Ambient Cancellation S/W
- Integration with Fault Detection & Isolation S/W
- Frequency range: 10 KHz - 1 GHz
  - higher frequency units due in 1999

System Requirements:

- A minimum of two CASSPER® receivers
- A CASSPER® Controller
- A Pentium Class (WINDOWS 95/98/NT) or PowerPC Class (Mac OS) Computer with GPIB card. At least 64 MB of RAM is recommended
- Regulatory Emissions Software
- Ambient Cancellation Software
- Fault Detection & Isolation Software
- Third party antennas and probes



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CASSPER™

Fault Detection & Isolation

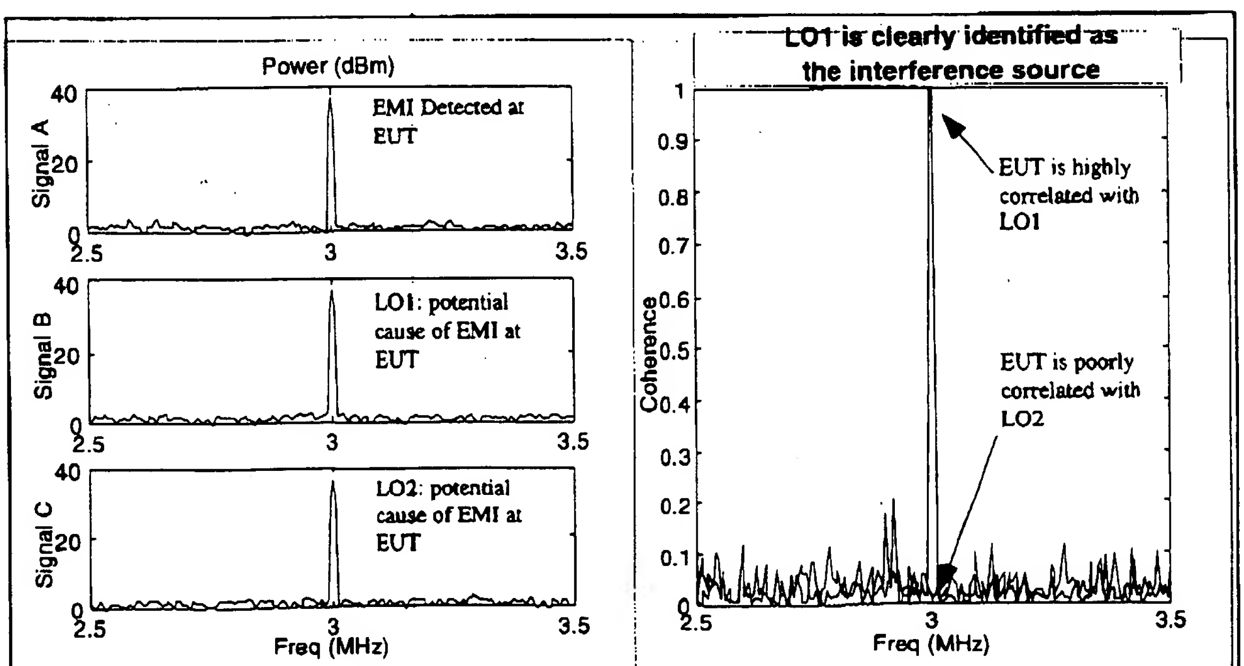
*Eliminate the guess work out of EMI fault detection and source localization by measuring the correlation of similar signals. Only CASSPER®'s **Patent Pending** architecture can provide you with an effective Fault Detection and Isolation capability.*

Specifications:

- Coherence function is used to pinpoint the source of EMI. The Coherence function measures the correlation among multiple signals, even when they are at the same center frequency
- Ability to view multiple receiver input simultaneously for determining noise source
- Frequency range: 10KHz - 1GHz
- Full integration with the Emission and Ambient Cancellation software
- The same flexible hardware and software configuration can be employed for EMI investigation of:
  - circuit boards
  - electronic boxes & systems
  - manufacturing plants

System Requirements:

- A minimum of two CASSPER® receivers. One near the suspected EMI source, the other near the location being interfered with
- A CASSPER® Controller
- A Pentium Class (WINDOWS 95/98/NT) or PowerPC Class (Mac OS) Computer with GPIB card. At least 64 MB of RAM is recommended
- Fault Detection and Isolation Software



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CASSPER™

True Ambient Cancellation For Outdoor Test Sites

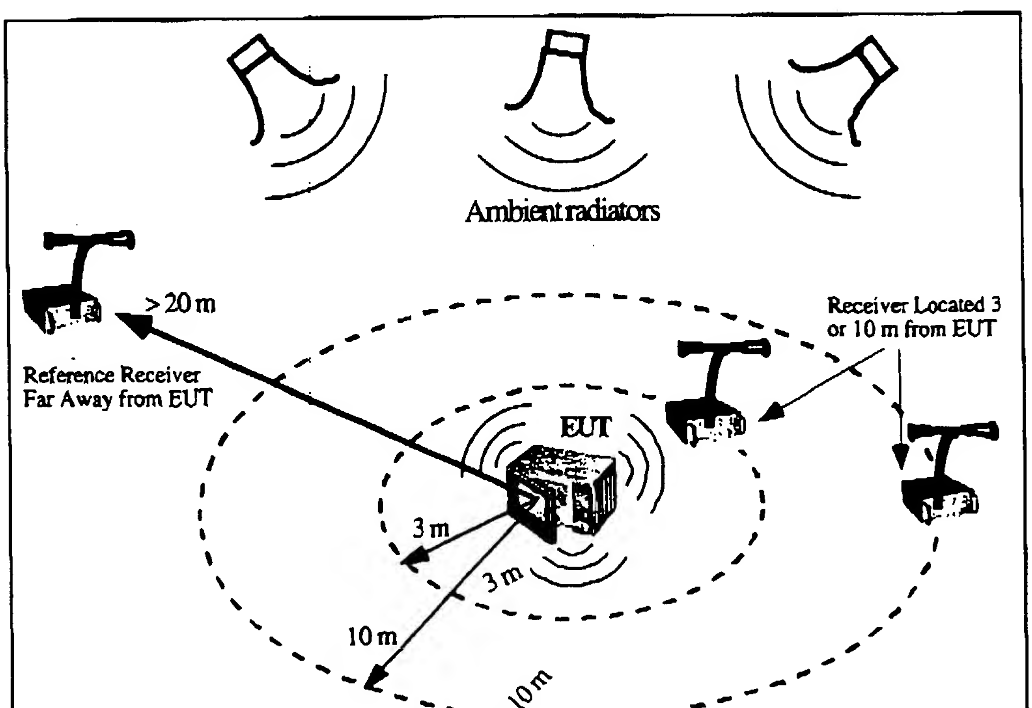
*Eliminate the need for a expensive anechoic chamber by reducing your ambient noise by as much as 45 dB from your outdoor test range. Only CASSPER®'s **Patent Pending** architecture can provide you with an effective outdoor emission test range.*

Features/Specifications:

- Operates in the investigation window to speed up testing and operations
- Window opens directly to marker/frequency under investigation
- Peak, peak hold, and average functions
- Variable bandwidth selection
- Up to 45 dB cancellation of ambient signals
- Frequency range: 10KHz - 1GHz
- System dynamic range: 90dB
- Instantaneous dynamic range: 60 dB
- Full integration with the Emission and Fault Isolation software

System Requirements:

- A minimum of two CASSPER® receivers. One near the EUT, the other far from the EUT
- A CASSPER® Controller
- A Pentium Class (WINDOWS 95/98/NT) or PowerPC Class (Mac OS) Computer with GPIB card. At least 64 MB of RAM is recommended
- Ambient Cancellation Software



#5

EMP Hardness Surveillance Test Technique Based on Ambient Man-Made Radiators

Dr. Parviz Parhami, John Robinson, Mike Marino, Lee Olson, Stephen Watkins, and Paul Fleming
SARA, Inc., 15261 Connector Lane, Huntington Beach, CA 92649-1117

Mike Rooney
Defense Threat Reduction Agency (DTRA), 6801 Telegraph Road, Alexandria, VA 22310-3398

Abstract

As prescribed in MIL-STD-188-125, EMP Hardness Maintenance/Hardness Surveillance (HM/HS) of hardened C^4I facilities includes CW illumination testing for evaluation of facility EM shielding integrity. This test technique is equipment, labor, and time intensive and it generally intrudes on normal facility operations. In addition, due to time and resource limitations, HS testing is performed infrequently (every few years per site) — reducing the confidence in the EMP hardness or survivability of these important assets over time. The need for a less intrusive, low cost HS test technique is apparent.

Advanced signal processing techniques, in conjunction with physically distributed synchronized receivers, have created new possibilities for EMP Hardness Surveillance (HS) applications. Specifically, external ambient man-made EM radiation can effectively be used for monitoring the EM shielding integrity of EMP hardened facilities; minimizing or even obviating the need for the traditional, intrusive, resource intensive, active CW radiation sources.

Introduction

It is a well known fact that commercial radio or TV receivers have either poor or no reception when operated inside EM shielded facilities. EMP engineers have long desired to exploit this fundamental but intuitive phenomena as the basis for a simple, low cost HS test technique. Conceptually, such a technique involves continuous or periodic monitoring of the EM shielding integrity of a facility, using only receivers for monitoring the ambient signals, and sounding of an alarm when hardness maintenance is required.

Realization of this concept has been stymied by the lack of time and frequency synchronized receivers for simultaneously monitoring the ambient fields inside and outside the shielded facility. Recent demonstrations have successfully shown, however, that use of advanced signal processing techniques in conjunction with physically distributed synchronized receivers can provide adequate sensitivity for this revolutionary application.

Ambient HS Test Technique Requirements

The requirements for an instrumentation system capable of monitoring facility EM shielding integrity using ambient man-made radiators as the excitation signal are:

- A minimum of two physically distributed receiver channels to measure the ambient fields outside the shielded facility and the induced response at test points inside the facility. The receivers must be time and frequency synchronized to enable comparative analysis of the measured data. At a minimum, the interior receiver sensitivity must be better than −100 dBm.
- Wideband signal processing algorithms capable of processing the two received channels in order to isolate and correlate related signals between them.

Candidate Instrumentation System

The requirements defined above have been realized in CASSPER®, a new generation of instrumentation system developed by SARA under contract to the Air Force Research Laboratory (AFRL). It was designed for the purpose of providing the EM community with a new, versatile tool for efficiently and accurately characterizing transfer functions, especially in high noise environments, without causing EM interference (EMI) in neighboring electronic equipment. CASSPER® is the result of an innovative application of the following dual technologies (Patents pending):

Digital Distributed Instrumentation.

As depicted in Figure 1, CASSPER® has a distributed and expandable architecture facilitated through the use of digital fiber optic links as opposed to the familiar, traditional analog fiber optic links. All modules in the physically distributed CASSPER® system are time and frequency synchronized. The entire system performs as a single cohesive instrument — a feature essential for implementing wideband signal processing algorithms. Triggered by a command from the central computer, CASSPER® receivers simultaneously detect and digitally record signals at each location. The recorded data are then digitally transmitted to the central computer for wideband signal processing and analysis.

Spread Spectrum Excitation and Processing.

CASSPER® is capable of spread spectrum operation to take advantage of wideband random or pseudo-random excitation and response signals, such as those from ambient man-made EM radiation.

The spread spectrum mode of operation includes calculation of the coherence function Γ defined as:

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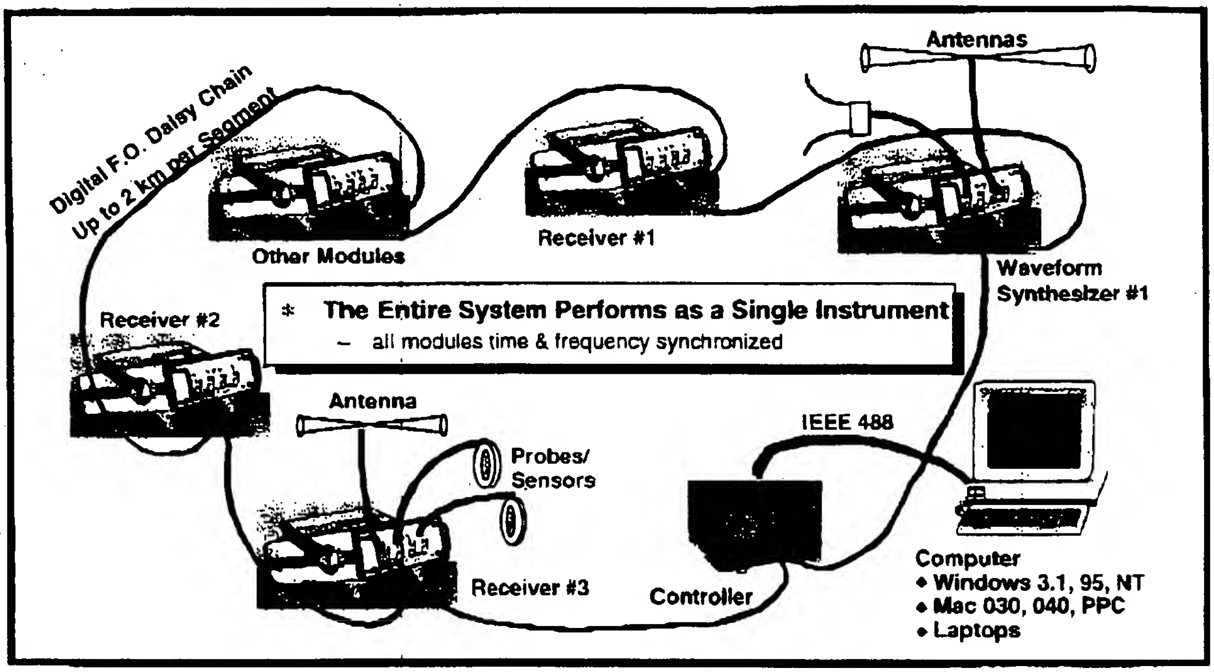

Figure 1. CASSPER® instrumentation system has a distributed architecture so it can simultaneously record time and frequency synchronized data at multiple locations. The received data are recorded at each location and digitally transmitted to the central computer for signal processing via digital fiber optic links.

$$\Gamma^2(\omega) = |S_{yu}(\omega)|^2 / [S_{uu}(\omega)\, S_{yy}(\omega)] \qquad (1)$$

where S_{uu} and S_{yy} are the autocorrelation of the wideband signals recorded outside (reference) and inside the facility (response), respectively, and S_{yu} is the cross correlation of the two signals. The non-parametric transfer function or shielding effectiveness **H**, is derived using:

$$\mathbf{H}(\omega) = S_{yu}(\omega) / S_{uu}(\omega) \qquad (2)$$

A valid EM shielding effectiveness estimate at a given frequency requires that the reference signal **u**, and response signal **y**, be highly correlated at that frequency — i.e., the coherence function Γ near one. For less than perfectly correlated interference or noise, the shielding effectiveness estimate error is related to the coherence as follows:

$$\varepsilon(|\mathbf{H}(\omega)|) \sim \{(1-\Gamma^2(\omega))/(2n\Gamma^2(\omega))\}^{1/2} \qquad (3)$$

where **n** is the number of averages. Thus, as the coherence becomes small, the normalized random error increases as one over the coherence. The normalized random error approaches 0 as coherence nears 1. Figure 2 demonstrates this behavior for various values of **n**.

The current version of CASSPER® is capable of capturing a 3MHz wide signal about a center frequency selected in the 10KHz - 1GHz range. At each center frequency, the 3MHz wideband signals are simultaneously digitized and recorded by all CASSPER® receivers. These receivers are frequency synchronized to a single local oscillator clock transmitted through the digital fiber optics loop. This is an essential feature of the system since the coherence Γ between the data channels is destroyed even if the two receiver clocks drift as little as 200-300 Hz. Each 3MHz wideband signal is sampled at 12 MHz using a 12 bit converter. Each receiver can be programmed to store up to 64,000 time series samples of the 3 MHz signal.

For the ambient hardness surveillance application, the system was programmed to perform a non-parametric signal processing operation on the simultaneous reference and response channel measurements. To achieve relations shown in Equations 1 and 2, the Welch method with no overlap (also referred to as the Bartlett method) was used to estimate the auto- and cross-correlations[1]. The processing steps are:

1. Each receiver's digitized measurements are divided into smaller sections or time windows.
2. For each section, the data is convolved with a Hanning window function.
3. Each section's data is decomposed into its spectral components using a discrete Fourier transform (DFT) algorithm.
4. The reference receiver's DFT data is multiplied by its complex conjugate to produce the auto-power spectrum of the reference.
5. The response receiver's DFT data is multiplied by its complex conjugate to produce the auto-power spectrum of the response.

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[1] "Engineering Applications of Correlation and Spectral Analysis", by Julius Bendat & Allan Piersol, 2nd Edition, 1993, Publisher John Wiley & Sons, New York, N.Y. pages 71-76.

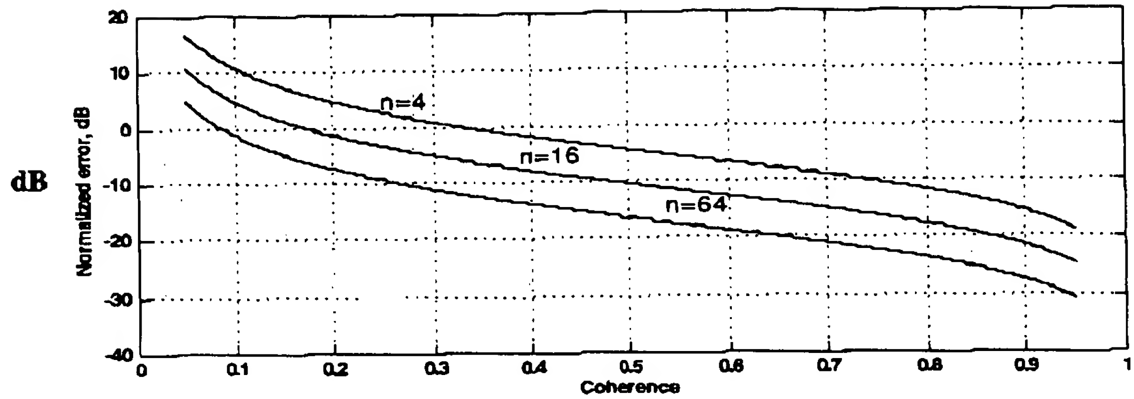

Figure 2. Error in the shielding effectiveness estimate as a function of coherence and number of averages.

6. The response's DFT data is multiplied by the complex conjugate of the reference's DFT data to produce the cross-power spectrum.
7. Steps 2 through 6 are repeated for each data section.
8. The results from each section are added together. This gives a sum of the auto-power spectrum of the reference, a sum of the auto-power spectrum of the response, and a sum of the cross-power spectrum.
9. The transfer function or shielding effectiveness estimate is the cross-power spectrum divided by the auto-power spectrum of the reference (see Equation 2).
10. The coherence function estimate is the square of the cross-power spectrum divided by the product of the auto-power spectrum of the reference and the auto-power spectrum of the response (see Equation 1).

The above signal processing procedure was successfully implemented into CASSPER® and recently demonstrated in the following proof-of-concept test program.

Proof of Concept Test Program

The shielding effectiveness of DTRA's 3m shielded room, located in SARA's Albuquerque, NM offices, was monitored using ambient man-made radiators present in the Albuquerque area. This test was conducted during a three-day period in February 1999. Due to time and resource limitations, the test objectives were limited to:

- Demonstrating the coherence detection technique for identifying the common ambient signals at both the reference and the response channels.
- Demonstrating the utility of the technique in detecting various degradation levels of the shielded room.

As shown in Figure 3, a log periodic antenna was used as the reference channel located 4.5 m away from the shielded room. A 1m loop antenna was used just inside the shielded room and perpendicular to the door, to represent the response channel. No attempt was made to calibrate the antennas over the 10KHz-1GHz range. The exact location and orientation of the two antennas were kept unchanged throughout the experiments.

The entire 10KHz to 1GHz spectrum was scanned using two CASSPER® receivers without any consideration given to the known local radiator center frequencies. Each scan of the entire spectrum was achieved in about 8 minutes, during which over 20,000 frequency points (frequency resolution of 47KHz) were recorded using 32 averages.

The test results presented in the following subsections clearly demonstrate the success in meeting the two program objectives.

Door Open Experiment

A series of experiments were performed with the shielded room door wide open in order to:

1. Validate the coherence detection technique — which is the first program objective, and
2. Evaluate the short-term repeatability of the test setup — necessary for meaningful degradation experiments.

Figure 4 (top plot) depicts the 1GHz scan of the shielded room with the door wide open. As expected, man-made radiators were successfully detected at several hundred frequency points spread over the entire 1GHz range. To have high coherence, a given time series signal must be detected at both the reference and response channels. The higher the coherence, the stronger the two signals are correlated. The coherence detection technique is further illustrated in the lower plot of Figure 4 which only displays data over the commercial FM band. Strong Albuquerque FM stations consistently resulted in coherence of 0.8 or higher, which in turn, will yield accurate shielding effectiveness estimates.

The lower coherence values, say 0.3-0.8, are due to poor signal to noise ratio (S/N) in the response data. The wide band processing identifies and "pulls" the desired ambient signal out of the response noise floor.

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The experiment, the results of which are shown in Figure 4, was repeated three hours later using the same configuration, i.e., shielded room door open, in order to evaluate the short term repeatability of the test procedure. The repeat measurement followed the degradation experiment described later in this paper.

For the two repeat measurements, the top graph of Figure 5 plots the number of frequency points in common for a given coherence threshold. For example, about 100 common frequency points were found to have a coherence of 0.8 or higher, and about 300 common frequency points were found with coherence factor of 0.5 or higher. The remaining 1800 points had poor (<0.5) coherence. The corresponding repeatability statistics are shown in the lower plot of Figure 5.

It is remarkable to note that, at any coherence threshold level, the average error between the two repeat measurements was consistently less than 1 dB. While on the average the two repeat measurements were virtually identical, the corresponding standard deviation clearly shows the spreading of the individual sample error as the coherence threshold is reduced. The standard deviation consistently remains below 3dB for coherence > 0.5, and appears to completely fall apart for coherence < 0.1. Some general observations can be made based on this limited repeatability experiment:

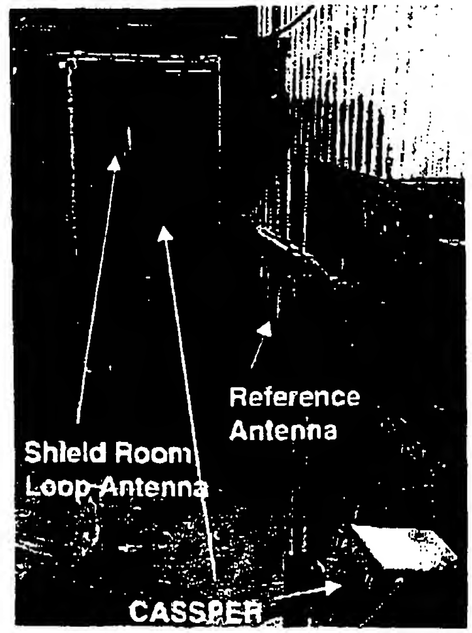

Figure 3. Experimental setup used for the proof of concept experiment. The 3m shielded room has better than 100dB shielding effectiveness once the RF door seal is engaged.

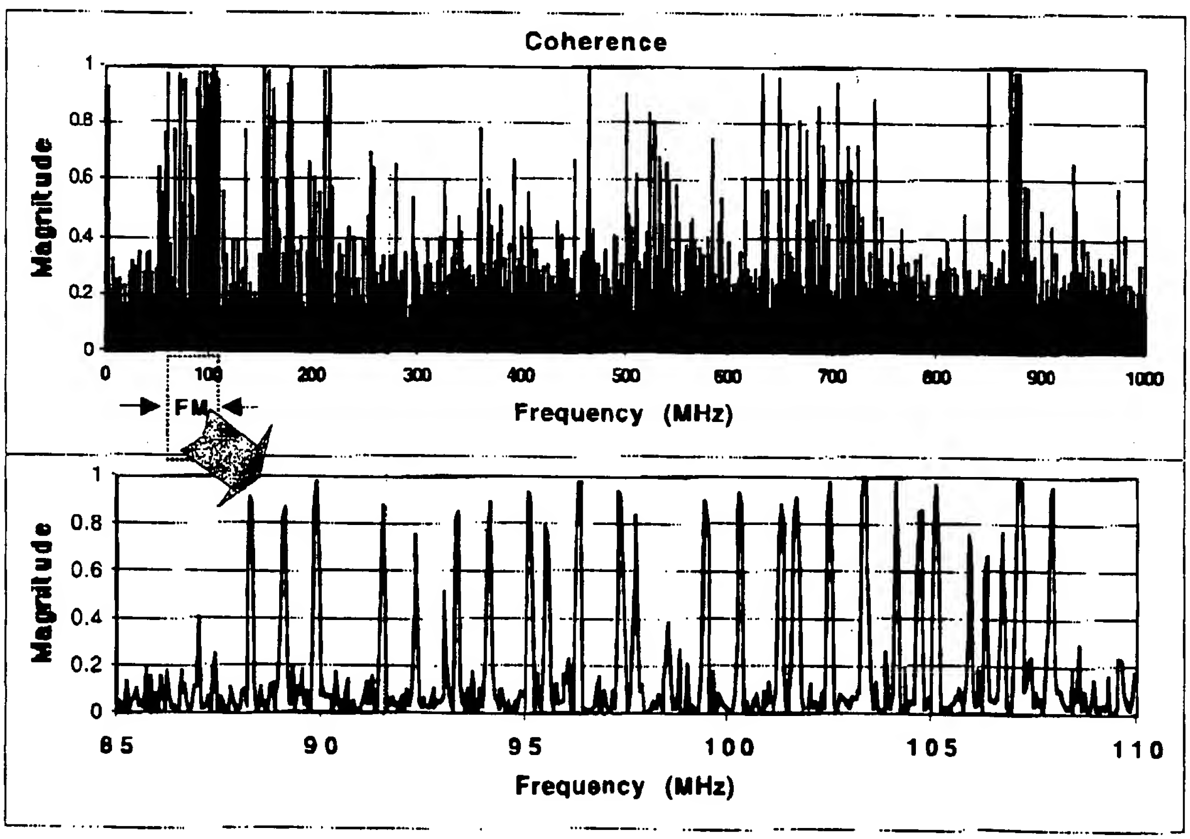

Figure 4. Top Plot: Coherence plot for shielded room door open. Numerous manmade stations were simultaneously detected, by both the reference and response test points, over the entire 1GHz frequency range. The FM band portion of the top plot is expanded and shown in the bottom plot. Note that every predominant Albuquerque FM station is clearly identified by a strong coherence spike.

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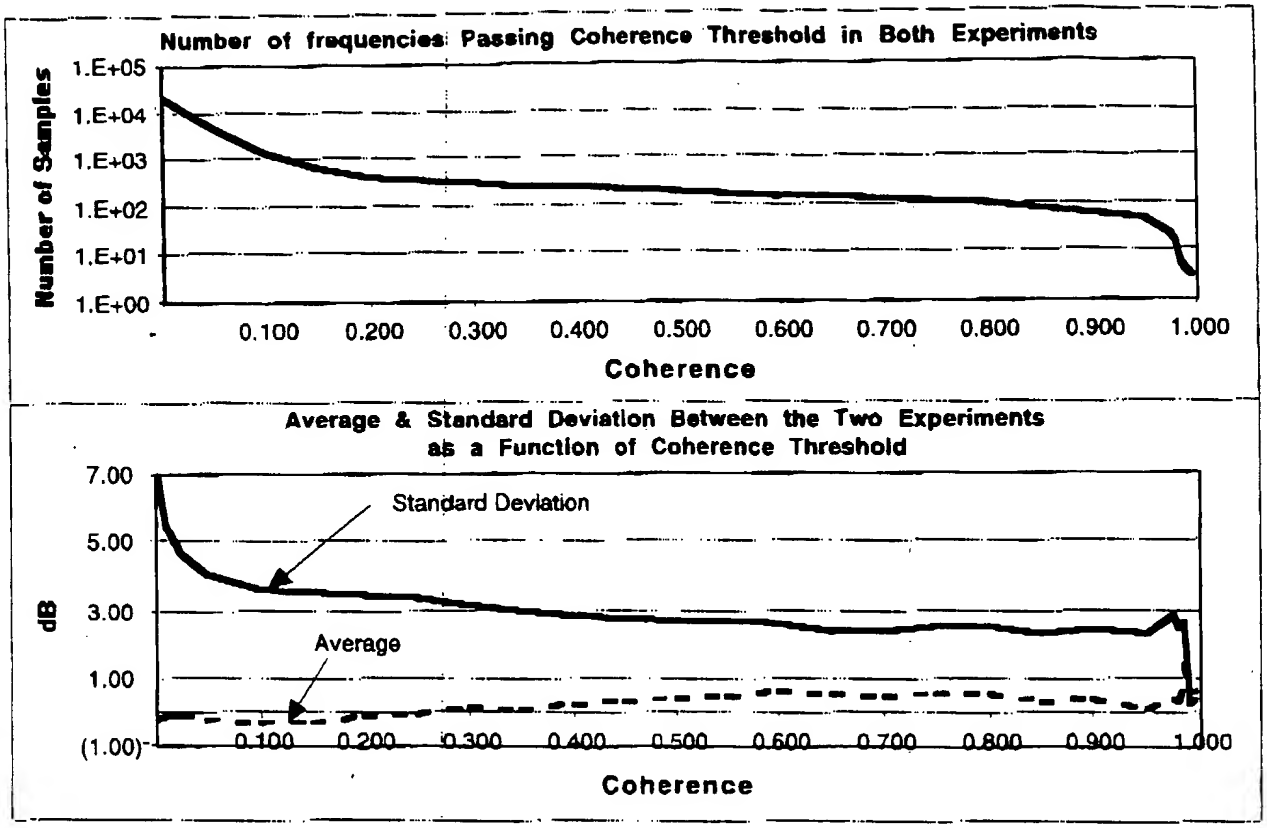

Figure 5. Short term repeatability data is shown for two scans made three hours apart for the "door open" configuration. The top plot shows the number of common frequencies between the two scans as a function of coherence threshold levels. The bottom plot displays the average and standard deviation between the transfer function estimates at the common frequency points as a function of coherence threshold levels.

- The shielding effectiveness estimates when coherence > 0.8 can be directly used as a degradation measure. For lower coherence thresholds, other statistical metrics should be developed.
- The change in the "average" metric, as defined in Figure 5, can be an effective statistical degradation indicator. Significant shift in the average can only be caused by the change in facility configuration. Additional study is required to determine optimum coherence threshold levels for such a metric.
- The "standard deviation" metric can be used to screen out unstable man-made radiators, such as mobile stations which continuously change their orientation with respect to the facility. The "standard deviation" metric can be used to identify and delete these potentially unstable frequencies at a specific facility.

Degradation Experiment

The DTRA's shielded room has a RF seal which, when engaged, increases the shielded effectiveness of the room to over 100 dB. This presented an excellent opportunity for conducting an effectiveness degradation experiment using the Albuquerque ambient radiators.

Four shielded room configurations were consecutively tested over a three hour period. They were:

1. Door closed – RF seal activated. The room is expected to have over 100dB shielding, although we were not able to independently verify it due to time limitations.
2. Door closed – RF seal deactivated, door not touched. We expect some minor shield degradation over the first configuration.
3. Door closed – RF seal deactivated, seal broken. The door was tapped so that the slight warp around the door, which is pulled in by the RF seal, appears. The shield degradation is expected to be significant in this configuration, and
4. Door wide open. This is the same configuration used for the repeat experiment. It represents the maximum degradation of the room.

As before, each 1GHz scan was conducted in 3 MHz steps, used 32 averages, and yielded over 20,000 samples at 47 KHz frequency steps. Each scan was completed in 8 minutes. The procedure is extremely data rich and the data can be analyzed using many techniques. The key to the success of this method, however, is the derivation of

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simple and easy-to-track metrics for monitoring the shielding effectiveness of the shielded room.

Figure 6 shows one such metric and the potential for formulating other types of metrics. Shielding effectiveness estimates for frequency points with coherence > 0.5 are displayed in the four scatter plots, corresponding to each of the four shielded room configurations. The following are some general observations:

- The number of frequency points detected with coherence > 0.5 is a simple and effective metric for tracking the shielding effectiveness of the room.
- The scatter plots clearly show the increased penetration of specific manmade radiators (as highlighted in Figure 6) as the shield is degraded. This phenomena can be used as the basis for more advanced and perhaps more stable metrics for tracking degradations.

Conclusions

We have successfully demonstrated the feasibility of using manmade ambient radiators for monitoring the shielding effectiveness of facilities. Further research in this area includes:

- Developing different types of metrics for tracking shielding effectiveness.
- Establishing procedures for establishing baseline levels for the various metrics, and
- Automatically adapting to the local ambient environments and use the necessary metric(s) to report on the health of the shielded facility.

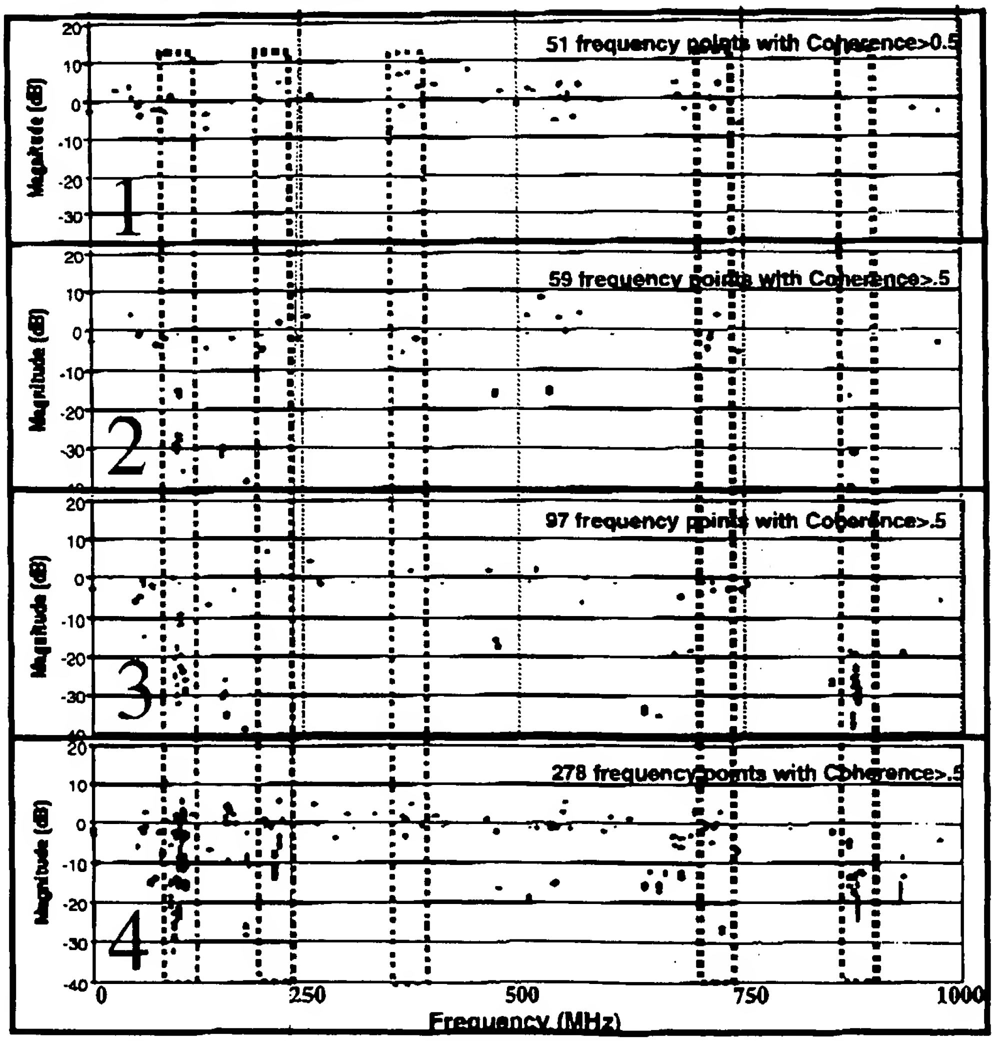

Figure 6. Transfer function scatter diagrams for the four shielded room configurations. Configuration 1 is with door closed and RF seal activated. Configuration 4 is with the door wide open. Note the increase number of frequency points with coherence >0.5 as the shielded room is increasingly degraded. As highlighted by the dotted line, also note the pattern of the scatter diagram which tends to bunch around local stations.

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

SERIAL NO: 09/497,292	Examiner: Kevin M. Burd
Filing Date:	Group Art Unit: 2734
Inventor: Marino	**REVOCATION OF COUNSEL and APPOINTMENT OF NEW COUNSEL**
For: System and Method for Measuring RF Radiated Emissions in the Presence of Strong Ambient Signals	

Box Non-Fee Amendment
Commissioner of Patents and Trademarks
Washington, D.C. 20231

Dear Sir:

The undersigned having, on or about the 3rd day of February, 2000, appointed Kit M. Stetina and others, of Stetina, Brunda, Garred & Brucker, as attorneys to prosecute an application for letters patent, which application was filed 02/03/00, for SYSTEM AND METHOD FOR MEASURING RF RADIATED EMISSIONS IN THE PRESENCE OF STRONG AMBIENT SIGNALS, Serial Number 09/497,292, hereby revokes the power of attorney then given to Kit M. Stetina and to the attorneys in the firm of Stetina, Brunda, Garred & Brucker, and appoints in their stead, JOHN J. MURPHEY, Registration Number 24,896, to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith. Address all correspondence to: JOHN J. MURPHEY, Attorney at Law, MURPHEY & MURPHEY, A.P.C., Pacific Center One, Suite 260, 701 Palomar Airport Road, Carlsbad, California 92009-1027; telephone number (760) 431-0091; facsimile number (760) 431-9441; e-mail: JMurphey@murphlaw.com.

Steven Watkins, C.E.O.
CASSPER Instrumentation Systems, Inc.

Dated: 12/4/00

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